Report of survey

SANTA MARIA RIVER WATERSHED

California

Program for runoff and waterflow retardation and soil erosion prevention for flood control purposes

U.S. DEPARTMENT OF AGRICULTURE

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UNITED STATES DEPARTMENT OF AGRICULTURE

SANTA MARIA RIVER WATERSHED

CALIFORNIA

Program for Runoff and Waterflow Retardation and Soil Erosion Prevention

Pursuant to the Act approved June 22, 1936 (49 Stat. 1570), as amended and supplemented.

February 1951

(Revised February 1954)

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INTRODUCTION

Authority. This survey report is submitted under the provisions of the Act approved June 22, 1936 (49 Stat. 1570) as amended and supplemented.

Scope. This report outlines a program of watershed treatment for runoff and waterflow retardation and soil erosion prevention needed in the Santa Maria River watershed in California.

The watershed program is composed of two groups of measures. One group consists of measures primarily for flood prevention, hereinafter called flood-prevention measures (A Measures), which are not now normally being installed under existing authorities for current national programs of the Department of Agriculture. The other group consists of measures used for the conservation of watershed lands which contribute directly to flood prevention, hereinafter called land-treatment measures (B Measures), and which are being installed under existing authorities for such programs.

This report presents recommendations for authorization of the flood-prevention measures under the Flood Control Act of June 22, 1936, as amended and supplemented, and for installation of the land-treatment measures under existing authorities concurrently with the flood-prevention measures.

Need for the Watershed Program. The investigation revealed that deterioration of crop and grazing land through exhaustive use and deterioration of wildland by fires have been major factors contributing to damaging floods in the Santa Maria drainage. Deterioration

will continue and, unless checked, will tend to increase further the rate of runoff and erosion and seriously affect the efficient long-time operation of reservoirs and other flood-control works under consideration by other agencies in the basin.

The flood and conservation problems are the consequence of man's encroachment upon the natural flood plain, and his conversion of watershed lands to his own needs. The building of towns, roads, and bridges and the cultivation of flood plain lands has upset the original balance of the river plain and its source. This, together with erosion and excess runoff caused by improper cultivation, over-grazing, and unnecessary forest fires, contributes to the hazards of life on the flood plains.

The population of the basin is about 23,000. The principal occupation is agriculture, with an annual gross return of about $27,000,000. In 1940, about 13,400 people in the Santa Maria Valley were living in a flood-hazard zone. The probable maximum flood may take a course affecting a large proportion of the number directly, and all of them indirectly. Erosion during periods of heavy rain-fall affects more or less the whole of the farming population. Periodic large discharges have caused destruction and impairment of agricultural land through bank erosion. It is estimated that floodwater and sediment damage will average about $591,800 annually under a continuation of present watershed deterioration. Not in-cluded in the above figures are the sedimentation damages which will occur, under continuation of present watershed deterioration, in the improved channels and the percolation areas.

Local interests and public agencies are developing plans to reduce the flood hazard and improve the irrigation water supply by a combination of reservoirs and levees. Although such measures will reduce the amount of flood damage found by this investigation, the program for runoff retardation and erosion reduction recommended herein will aid materially in maintaining the effectiveness and augmenting the results of any structural works constructed on the main river, and will provide substantial protection and conservation benefits to the areas not protected by major structures.

RECOMMENDATIONS

It is recommended that:

(a) The Secretary of Agriculture be authorized to install the flood-prevention measures on a cost-sharing 1/ basis with local interests during a 20-year period in the Santa Maria River watershed, under the provisions of the Act of June 22, 1936, as amended and supplemented, except the measures which are proposed for installation on land under the jurisdiction of a Federal agency other than the Department of Agriculture, and that the head of such other Federal agency be authorized to install the flood-prevention measures which are proposed for installation on land under the jurisdiction of such agency. The estimated total Federal cost of all flood-prevention measures is $771,200.

1/ The share of the cost to be borne by local interests may consist of cash, labor, materials, equipment, land, easements, rights-of-way, and other contributions.

(b) The land-treatment measures, for which no additional authority is requested herein, be applied under existing authorities concurrently with the installation of the flood-prevention measures to assure the proper functioning of the program.

(c) As a condition precedent to the installation of the program, cooperating State and local agencies be required to furnish assurances satisfactory to the Secretary of Agriculture with respect to their ability and willingness to operate and maintain the flood-prevention measures on non-Federal land.

(d) The authority of the Secretary of Agriculture, or the head of any other Federal agency concerned, to carry out the flood-prevention measures shall be supplemental to all other authority vested in him, and that nothing in this report shall be construed to limit the exercise of powers heretofore or hereafter conferred on him by law to carry out such measures or other measures that are similar or related thereto.

(e) The Secretary of Agriculture, or the head of any other Federal agency concerned, be authorized to construct such buildings and other improvements as are needed to carry out the flood-prevention measures.

DESCRIPTION OF WATERSHED

The Santa Maria River watershed occupies 1,873 square miles or 1,198,720 acres in the south coastal region of California, see Map 1.

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The accompanying map shows the general location and outline of the watershed. The Santa Maria Valley proper, comprising an area of about 244 square miles or 155,000 acres, lies in Santa Barbara and San Luis Obispo Counties. It is located about 130 miles northwest of Los Angeles and 60 miles northwest of Santa Barbara. The upper part of the watershed extends into Kern, Ventura, and San Luis Obispo Counties.

The watershed is formed by three major natural subunits: (1) the Santa Maria Valley in the coastal region below the confluence of (2) the Cuyama River which occupies the north half of the upper watershed, and (3) the Sisquoc River on the south half. The Cuyama and Sisquoc River converge at Fugler's Point at the eastern edge of the Santa Maria Valley to form the Santa Maria River. The broad, fertile, and intensively developed agricultural valley of the Santa Maria is flanked by low hills and mesas. The Sisquoc River is hemmed in by the rugged chaparral-covered mountains of the Sierra Madre range on the north and the San Rafael range on the south. The Cuyama River, north of the Sisquoc, originates in the steep mountainous headwaters at the extreme southeastern tip of the watershed. The drainage basin occupies almost three-fifths of the total watershed area. The interior basin is a relatively flat valley floor in which the river has become entrenched. The Cuyama Valley is flanked on the north by the almost barren Caliente Mountains and on the south by the rugged chaparral-covered Sierra Madre range.

The topography of the Santa Maria River watershed reflects the geologic history of the drainage basin. The two principal mountain ranges, the Sierra Madre and San Rafael, have been formed by uplift which arched the sedimentary beds, breaking them along the faults to form the Cuyama and Sisquoc Rivers. Subsequent stream cutting and erosion has carved a steep, rugged topography capable of yielding high erosion rates and rapid storm runoff. The non-mountainous portions of the watershed, the Cuyama and Santa Maria Valleys, are structural down-folded basins filled to depths of several thousand feet with clay, sand, and gravel by the streams discharging into the valleys.

Similarly, geology has had a direct influence on the soils of the watershed. The soils of the two great valleys, the Cuyama and the Santa Maria, are predominantly alluvium. Infiltration capacities are good except where certain land-use practices have compacted the soil. Erosion in the valleys is not a serious hazard except for bank cutting along the rivers. Overlaying the Quaternary terraces above the floor of these two valleys are large areas of soil derived from coastal plain and old valley-filling deposits, variable in texture and erodibility. The light-textured soils are highly erodible, particularly under cultivation.

In the Bradley Canyon area some 2,870 acres of moderately to well-developed aeolian soils occupy the Quaternary terraces. Past cultivation has resulted in the abandonment of much cropland as the result of severe sheet and gully erosion.

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The soils of the Caliente, Sierra Madre, and San Rafael Mountains are predominantly residual on moderately or well-consolidated sediments. Under the stabilizing influence of undisturbed natural cover a good soil depth has developed. Depletion of the cover either by fire or excessive grazing has been accompanied by high erosion rates and accelerated storm runoff.

The soils of the Cuyama "badlands" in the northeast corner of the watershed are also residual but developed from poorly consolidated silt beds and coarser sands which erode easily.

A few isolated areas of residual soils of heavy texture formed from metamorphic, volcanic, or granitic rocks are found in Aliso Canyon, the lower Cuyama, Nipomo, and Sawmill Mountain area. Their erodibility as well as infiltration capacity is low although the parent material has high water storage capacity.

Sand dunes occupy an area immediately adjacent to the coast. The area is about 8,400 acres in size, eight miles long and 3-1/2 miles wide at the point of greatest width. Aeolian soils classified in the Oakley series are located chiefly on the Nipomo Mesa and on the table land between Santa Maria and Orcutt. The total area of these soils is approximately 26,000 acres.

Climate, geology, and soils largely determined the original natural cover found in this watershed. A century of use has altered the native plant cover drastically. Cultivation, livestock grazing, and wildfire have changed all but a relatively small portion of the total basin area.

At present approximately 32 percent of the watershed is covered by chaparral, principally in the rough, mountainous portion where it is protected to stabilize steep mountain slopes and maintain favorable runoff and erosion conditions. Denudation of any part of this area has a significant influence on flood runoff and erosion. The grass and open-woodland and pinon-juniper types, occupying respectively 19 and 11 percent of the area, are used largely for livestock range. Its contribution to the flood and sediment problem is dependent upon the intensity of range use. The remaining types, mixed sage, oak-woodland, and mixed conifer, totaling 17 percent of the watershed, also used to a limited extent for grazing, contribute only slightly to flood runoff and erosion.

Approximately 11 percent of the watershed is classed as semi-barren including stream channels, coastal sand dunes, urban areas, and very sparse pinon-juniper and sagebrush types.

The remaining 10 percent of the area formerly covered by grass and woodland is now cultivated, 4 percent in irrigated crops and 6 percent dry-farmed or nonirrigated crops.

Settlement in the Santa Maria Valley began in 1840 with the establishment of Rancho Guadalupe. The Mexican Government subsequently established many land grants; the larger grants included Guadalupe, Nipomo, Punta de la Laguna, Tepusquet, Sisquoc, and Cuyama. Livestock production became the principal industry and increased rapidly until the drought period 1862-64. Critical livestock losses caused large land holdings to be divided into smaller tracts and sold to

eastern settlers. Most of this land is still held in private hands. The rest has reverted to or remained in public ownership, now some 55 percent of the basin. Of the publicly owned land, 90 percent is national forest, 9 percent public domain, and 1 percent state land.

About 23,000 people live in the Santa Maria watershed; more than one-half of them in the city of Santa Maria.

The principal occupation in the Santa Maria River basin is agriculture with an annual gross return of about $27,000,000. Irrigation farming and livestock ranching are the two major sources of income. Irrigation was introduced in 1897 when the Union Sugar Company built a factory at Betteravia to process the sugar beets which were being grown on an increasing acreage. Gravity irrigation was limited to small acreages near the river. The first pumping plants, powered by steam, were costly and inefficient. Not until the early "twenties" when efficient motors and pumps were introduced did farming become intensive and vegetable growing expand rapidly. In 1947 approximately 36,700 acres were being irrigated from 317 wells. The crops grown were lettuce, cauliflower, carrots, seed flowers, alfalfa, and sugar beets. The current pumpage of about 65,000 acre-feet exceeds the safe yield by 14,000 acre-feet annually.

The agricultural industry in the valley is dependent upon the maintenance of economic pumping levels for its continuous prosperity. Irrigation in the Cuyama Valley is of recent origin. About 6,000 acres are now planted to irrigated crops, chiefly potatoes and alfalfa.

Livestock ranching occupies the land not usable for either irrigation or dry-land farming. Normally one-third of the agricultural income comes from this source.

Aside from the production and processing of agricultural products the other major industry within the watershed is oil production. Many years ago oil fields were developed near Santa Maria, Orcutt, and Sisquoc. Recently a major oil field was discovered in the Cuyama Valley which resulted in widespread leasing of both public and private land in the adjoining Sisquoc, Alamo, and Huasna drainages. As of May 10, 1950, Los Padres National Forest alone processed 1,769 applications for oil leases. Extensive exploration and oil drilling in the mountainous watershed areas will be accompanied by road building, sump construction, and preparation of derrick locations, all of which will create new and active sediment sources. This development will bring with it new hazards to the chaparral-covered mountains which serve as rainfall catchment basins and supply the usable flows of surface and ground waters essential to the economic development in these valley areas.

Long before the discovery of the Cuyama oil field, the number of forest users had increased from about 9,800 annually during the period 1911-25 to about 306,000 annually in 1949. As a result of this increased development and population growth the number of wildfires can be expected to increase proportionately. With the present level of fire protection, at least one fire can be expected for every 10,000 forest users.

FLOOD PROBLEMS

Records of floods dating back to 1811 show 25 floods of sufficient magnitude to cause widespread damage. In addition, many smaller floods have damaged local areas in the flood plain. Floods usually occur in February or early March. The last major flood was in 1914. Others occurred in 1909, 1910, and 1911. The floods of 1909 and 1914 were of equal magnitude of about 100,000 c.f.s.

Floodwater and Sediment Sources. The Cuyama River with its two principal tributaries, Huasna River and Alamos Creek, is the largest contributor of silt. The major sources are the semibarren badlands at the head of the drainage and the channel banks in the Cuyama Valley. The average rainfall of the badland area is low but summer cloudbursts are common. Sediment production from these lands would be high naturally but it has been augmented by "early day" fires and sheep grazing. The Cuyama River has cut a deep channel in the lower half of the Cuyama Valley. Enough material is available in the steep banks to load any flow of the river. Streams meandering over the upper portion of the Cuyama Valley and streams from the Caliente Mountains yield smaller sediment contributions. The semi-desert area, about two-fifths of the watershed, has very scant cover; consequently rainfall even in small amounts produces debris.

Floods from the Sisquoc River basin are short in duration but contribute nearly twice the volume of flows and peak discharges of flows as do the Cuyama floods. Sediment concentration in the flows of the Sisquoc under present watershed conditions is relatively low,

but the large volume of water makes this watershed, too, an important source of sediment. Shallow erodible soils, steep slopes, and high rainfall combine to make possible destructive flood flows whenever the cover is destroyed or materially reduced in density.

The Santa Maria River channel is a wide expanse of sandy river wash with little or no well-defined banks along the south side above the town of Santa Maria and on the north side west of Santa Maria in the upper Oso Flaco district. Floodwaters overflow the low banks at these locations and inundate the surrounding valley. The course of floodwaters is unpredictable in a valley as flat as the Santa Maria. Deposition of sediment, constriction of underwashed bridge sections, or debris accumulation around bridge piers could easily deflect the flow to traverse anywhere through the fertile truck cropland or through the towns.

Frequent flood flows come from low-yielding and abandoned cropland in Bradley Canyon, Gary Canyon, Guadalupe Lake, and the Santa Maria Mesa, all bordering the Santa Maria Valley. These local flows traverse agricultural land and roads. The Bradley Canyon floods also flow through the city of Santa Maria.

Floodwater and Sediment Damages. As indicated subsequently in this report, the Bureau of Reclamation and the Corps of Engineers have recommended a comprehensive project for the Santa Maria River to include a reservoir on the Cuyama River at the Vaquero site and levees on the Santa Maria River and lower Bradley Canyon. This project, when installed, will control nearly all flood damages in the Santa Maria Valley and the city of Santa Maria.

Annual damages from future floods in the overflow area without the Santa Maria Project are estimated at $710,000 by the Corps, based on long-term normal or true values. Since most of this damage will be eliminated by their project, this Department of Agriculture survey report does not include damage estimates for this portion of the watershed. Not affected by the Santa Maria Project is the Cuyama Valley, where intensive irrigation farming recently has been adopted. In the irrigated area, river banks are low and numerous old channels cross the land now under cultivation. It is estimated that annual losses will be $38,300 due to damages to crops, buildings, land, and roads when the river leaves its bed. Other areas which will not be controlled by the Santa Maria Project are Gary Canyon, Guadalupe Lake, Santa Maria Mesa and upper portions of Bradley Canyon. The annual damages in these areas amount to $4,900.

Upon completion of the Santa Maria Project the expected annual sedimentation damage to Vaquero Reservoir, without the USDA program outlined herein and assuming no increase in funds for watershed protection purposes, will amount to $548,600.

Other damages to the project which will be reduced as a result of a watershed program, but which have not been fully evaluated, include sedimentation damage to the improved channels and to the ground-water recharge areas.

On the basis of long-term projected prices, the estimated future average annual damages which will be affected by the USDA program are summarized in Table 1.

Table 1

ESTIMATED AVERAGE ANNUAL DAMAGES
Santa Maria River Watershed
(Long-term projected prices)

Type of damage	Average annual damage
	Dollars
Floodwater and associated sediment damage 1/	34,600
Indirect damage	8,600
Sediment damage to Vaquero Reservoir	548,600
Total average annual damage	2/ 591,800

1/ Includes damage to agriculture lands and crops, urban and industrial property, communication and transportation facilities, etc.

2/ Does not include damages in the Santa Maria Valley or damages to the improved channels and ground-water recharge areas.

ACTIVITIES RELATED TO FLOOD CONTROL

A number of agencies--local, county, State and Federal--have been working in the interest of flood and erosion control in the Santa Maria watershed.

At present there are no authorized or existing projects of the Bureau of Reclamation or Corps of Engineers in the Santa Maria area. However, the Santa Maria Project as outlined below has been proposed and reported on (H. D. 217, 83rd Congress, First Session, and Report on Survey, Flood Control, Santa Maria River and Tributaries, California, February 10, 1953).

The Santa Maria Project.--This project is a joint water conservation and flood-control project for the Santa Maria River Basin, in which the Bureau of Reclamation and the Corps of Engineers have integrated their planning efforts. The proposed construction consists essentially of a reservoir at the Vaquero site on the Cuyama River, and levee and channel improvements in the Santa Maria Valley.

The Department of the Army.--The levee and channel improvements along the Santa Maria River and Bradley Canyons as designed by the Corps of Engineers are a component part of the Santa Maria Project. The Santa Maria River levees are designed to protect the Santa Maria Valley from a peak flood of 150,000 second-feet (standard project flood peak assuming partial control by Vaquero reservoir). The lower Bradley Canyon channel and levee are designed to divert the standard project flood of 7,000 to 9,000 second-feet into the Santa Maria River. The cost of the Santa Maria levee and channel improvements is estimated at $9,540,000 and for Bradley Canyon at $735,000. The annual operation and maintenance cost is estimated at $47,500.

The Department of the Interior.--The Vaquero reservoir, as a part of the Santa Maria Project, was designed by the Bureau of Reclamation. It will have an area of 3,400 acres at the elevation of the top of the spillway gates, and a storage capacity of 214,000 acre-feet allocated as follows: 89,000 acre-feet for flood control, 80,000 acre-feet for water conservation, and 45,000 acre-feet for sediment retention. The estimated cost is $14,300,000. An average annual cost of $43,700 is estimated for maintenance, operation, and replacement. (All estimates are based on October 1950 prices.)

The Bureau of Land Management controls 60,200 acres of public domain land within the drainage. Issuance and supervision of grazing permits on the public domain are major activities. In addition, the Bureau issues and supervises oil leases on both the public domain and the national forest.

The Department of Agriculture, through its several agencies, is active on the watershed and promotes the installation and maintenance of measures and activities of interest to the objectives of the Flood Control Act.

The Forest Service administers 591,895 acres of national forest land within the watershed representing about 50 percent of the total area. The major activities have been fire control and management of the national forest range areas. Fire protection now encompasses about 635,000 acres. Other activities include the seeding of new burns to retard runoff and to hold the soil, road slope stabilization, and reseeding of range areas. The Forest Service cooperates with the State of California in the protection of State and private lands against fire. The Soil Conservation Service makes available technical assistance to farmers and cooperating State and Federal agencies interested in installing soil conservation measures. The Production and Marketing Administration's agricultural conservation program is applied on approximately 50 percent of the farm and rangelands within the watershed. A partial list of measures important in waterflow retardation and erosion control includes cover crops, crop residue management, subsoiling, spreader ditches, erosion control dams, range

improvements, and establishment of permanent pastures. The Federal-State Cooperative Extension Service promotes, among other activities, an educational program aiding farmers and ranchers in improving farm and ranch conservation practices related to soil erosion and flood control.

The State of California cooperates with the Department of Agriculture under the provisions of the Clarke-McNary Act of 1924. Federal assistance, amounting to about $14,300 in 1949, is provided for the protection of State and privately owned lands having a primary watershed value. Total expenditures for fire control by State and County are about $78,000 annually. The California Division of Forestry protects about 79,200 acres of Clarke-McNary watershed land in San Luis Obispo County. The 111,600 acres of privately owned land in Santa Barbara County are protected for the State by the Santa Barbara County Forestry Department.

The State Division of Highways also deals with local flood and erosion control problems in its highway construction and maintenance work.

Santa Barbara County constructed pile and cable jetties along the Santa Maria River after the 1909 flood to protect vulnerable sections of the south bank between Fugler's Point and the ocean. Periodically, repairs have been made and new jetties built. The County has spent about $400,000 on these improvements.

The City of Santa Maria constructed a limited capacity ditch in 1941 to divert flood flows from Bradley Canyon to the river east of

town. Although inadequate for large flows, it does provide limited protection to the business and residential section of Santa Maria.

The Santa Maria Valley Water Conservation District has issued reports periodically on flood-control and water problems in Santa Maria Valley. It also keeps records of well logs and water supply and collaborates with other agencies in plans affecting the area.

RECOMMENDED PROGRAM

The program recommended in this report is designed to meet the needs of the Santa Maria River watershed for runoff and waterflow retardation and soil erosion prevention. It consists of two groups of interrelated measures, which are designated as flood-prevention measures (A Measures), and land-treatment measures (B Measures).

The recommended measures were developed from studies, covering the entire area of the watershed, designed to provide a balanced and economically feasible remedial program. The proposed program assumes that the land-treatment measures are complementary to and must be carried out concurrently with the installation of those designated as flood-prevention measures. The present condition of the watershed lands and stream courses was considered in detail to develop the most effective combination of measures to reduce floodwater and sediment damages.

FLOOD-PREVENTION MEASURES

(A Measures)

Stabilizing and Sediment-Control Structures. Approximately 90 permanent structures will be constructed to stabilize

existing natural waterways now subject to accelerated erosion. Structures will include concrete chutes, drop structures and debris barriers in permanent waterways.

Subwatershed Waterway Improvement. About 27 miles of minor tributary stream channels will be improved and stabilized by such measures as vegetative planting in small gullies, establishment of vegetation in minor waterways, channel straightening, riprap and revetments.

Stream Channel Improvements. About 13 miles of stream channel will be improved to provide more adequate waterways for disposal of runoff from and through agricultural areas to the main river system to reduce sedimentation and destruction of land. Primary forms of improvement are channel enlargement and stabilization by revetment, drop structures, various types of lining, and diking.

Diversion Ditches and Dikes. About 55 miles of diversion ditches and dikes will be constructed to divert floodwater from the many unstable gully headings in the area and to convey runoff to stabilized outlet channels for orderly disposal through subwatershed waterways and stream channels to the river system.

Adequate provision has been made in the cost estimates of the above measures to provide for the installation and operation of measuring devices to test the effectiveness of the flood-prevention measures.

LAND-TREATMENT MEASURES

(B Measures)

Terrace Systems Including Outlets. Fifty miles of terraces on 5,000 acres will be constructed to provide erosion control on long slopes by intercepting runoff at intervals and to prevent excessive concentration of water.

Establishment of Cover Crops. Annual winter cover crops will be established on about 5,000 acres of cropland not now adequately protected from erosion.

Establishment of Permanent Cover. Permanent cover will be established on 8,500 acres of eroded cropland to prevent further deterioration and to reduce excessive sediment production from these areas.

Farm Ponds. Forty farm ponds will be constructed to provide additional needed water for stock and other uses.

Contour and Cross Slope Strip Cropping. Contours and cross slope strip cropping will be established on 2,000 acres of non-irrigated cropland to reduce erosion and excessive runoff from these areas.

Crop Residue Utilization. Crop residue utilization to improve present conditions will be practiced on sixty-two thousand acres of nonirrigated cropland.

Subsoiling. Subsoiling will be done on 35,000 acres of cropland to improve the soil-moisture relationship.

Protected Outlets. Two hundred protected outlets will be constructed to provide for orderly disposal of concentrated runoff from cropland to improve stream channels.

Cooperative Forest Fire Control. Fire protection will be intensified to reduce the average annual rate of burn on the 422,000 acres of non-Federal land of moderate fire hazard. The additional facilities required to meet the objective are principally buildings for equipment and personnel, motorized equipment, additional communication improvements, and limited access and transportation developments. The cost of installing and maintaining this measure will be in addition to regular agency activities.

Fire Control. Fire-control facilities will be expanded to reduce the annual rate of burn on 652,000 acres in Federal ownership. This area comprises a zone of high fire hazard and of high runoff and erosion potentials. It is in general the principal flood damage source and therefore requires a high degree of protection. The following items are typical of the kinds of improvements and work needed: Additional access and transportation facilities to permit speedier attack on all fires, improved detection and communication in reporting fire occurrences, additional water development for fire suppression, buildings for equipment and fire-control personnel, and provision for immediate treatment of burned areas.

Fencing. About 200 miles of fence will be constructed to improve livestock distribution and eliminate excessive use and trampling on present concentration areas during wet weather. Of the total fencing

recommended, 170 miles are on non-Federal land, and 30 miles on Federal land.

Stock-Water Developments. About 130 additional water developments will be installed to bring about more uniform utilization of range forage. New water developments will permit better use of range areas which have been little used because of inadequate watering facilities. Better utilization of these lands will relieve pressure on more heavily grazed areas. Of the total need, 82 are needed on non-Federal land, and 48 on Federal land.

Range Reseeding. Ranges will be reseeded to reduce erosion and improve the forage on 18,500 acres of depleted rangeland which would not produce an effective cover within a reasonable length of time without reseeding. About 11,500 acres of the reseeding will be done for non-Federal land, the balance for Federal land.

Technical Services, Open Land. Technical services will be made available for planning and applying the necessary land-use adjustments and for applying conservation measures on crop and range lands, and for integrating these measures with other measures included in the recommended program.

Educational Assistance. Landowners, operators, and other groups will be furnished educational assistance relative to the need for the recommended program and its purpose and objectives. Information will be supplied as to the manner in which landowners and operators now obtain services and assistance that are available through the various governmental agencies, and how they can and should, by their

own efforts, contribute successfully and most economically to the accomplishment of the over-all objectives. Intensified educational efforts will be directed to familiarizing farmers with the specific practices and measures essential to runoff and waterflow retardation and soil-erosion prevention, and how to install and apply these measures not requiring the assistance of a specialized technician. How to maintain such installations and measures will be emphasized. Instruction will be given on how to integrate all into a sound farm management system to produce the greatest benefits over a long period of time.

COST OF RECOMMENDED PROGRAM

The estimated cost of installing both the flood-prevention measures and the land-treatment measures is $4,756,900. It is estimated that local interests will provide 47 percent of the cost of installing these measures on non-Federal land. However, the allocation of Federal and non-Federal costs will vary by types of measures. The cost of installing land-treatment measures on non-Federal land will generally be borne in large part by individual landowners and operators since a large part of the benefit will accrue directly to the land on which the measures are applied. Flood-prevention measures, however, produce public benefits often of a dispersed nature, and extending far downstream. The Federal Government will install these latter measures on non-Federal land on a cost-sharing basis, and will provide a larger share of the cost of installation than in the case of land-treatment measures. The cost of installing,

operating, and maintaining both flood-prevention and land-treatment measures on Federal land will be borne by the agencies responsible for the administration of such land.

FLOOD-PREVENTION MEASURES

(A Measures)

The estimated cost of installing the flood-prevention measures is $1,127,800 (see Table 2). Of this cost, it is estimated that the Federal Government will expend $771,200 on non-Federal land, and that local interests will expend $356,600 on non-Federal land.

Local interests will be required to furnish without cost to the Federal Government all land, easements, and rights-of-way needed in connection with the installation of the flood-prevention measures; and will be expected to make any additional contributions that may be necessary to meet their proportionate share of the cost of installing these measures as determined by the Secretary of Agriculture to be equitable in consideration of the anticipated benefits from such measures.

The estimated annual cost of operating and maintaining these measures on non-Federal land is $26,700, which will be borne by local interests.

Table 2

ESTIMATED COST OF INSTALLING FLOOD-PREVENTION MEASURES
(A Measures)
Santa Maria River Watershed
(Long-term projected prices)

Measures 1/	Unit	Quantity	Cost: Federal 2/	Cost: Non-Fed.	Cost: Total
			Dollars	Dollars	Dollars
Stabilizing and sediment-control structures	No.	90	366,800	122,300	489,100
Subwatershed waterway improvement	Miles	27	74,000	49,200	123,200
Stream channel improvement	Miles	13	274,700	147,900	422,600
Diversion ditches and dikes	Miles	55	55,700	37,200	92,900
Total cost			771,200	356,600	1,127,800

1/ All measures are on private land.

2/ Includes cost of collecting basic data needed for guiding program installation and operation, and for testing effectiveness of the program.

LAND-TREATMENT MEASURES

(B Measures)

The estimated cost of installing the land-treatment measures is $3,629,100. (See Table 3.) Of this cost it is estimated that the Federal Government will expend $2,411,200 on Federal land and $461,600 on non-Federal land, and that local interests will expend $756,300 on non-Federal land. The estimated Federal cost of these measures on non-Federal land does not include financial assistance by the Federal Government such as Agricultural Conservation Program payments to landowners and operators. Any assistance of this kind

Table 3

ESTIMATED COST OF INSTALLING LAND-TREATMENT MEASURES
(B Measures)
Santa Maria River Watershed
(Long-term projected prices)

Measures	Unit	Quantity	Cost: Federal	Cost: Non-Fed.	Cost: Total
			Dollars	Dollars	Dollars
Terrace systems including outlets					
Non-Federal land	Mile	50	---	3,900	3,900
Establishment of annual winter cover crops					
Non-Federal land	Acre	5,000	---	23,000	23,000
Establishment of permanent cover					
Non-Federal land	Acre	8,500	---	78,200	78,200
Farm ponds					
Non-Federal land	No.	40	---	82,400	82,400
Contour and cross slope strip cropping					
Non-Federal land	Acre	2,000	---	18,000	18,000
Crop residue utilization					
Non-Federal land	Acre	62,000	---	111,600	111,600
Subsoiling					
Non-Federal land	Acre	35,000	---	11,300	11,300
Protected outlets					
Non-Federal land	No.	200	---	7,200	7,200
Cooperative forest fire control					
Non-Federal land	Acre	422,000	260,100	260,100	520,200
Fire control					
Federal land	Acre	652,000	2,350,900	---	2,350,900
Fencing					
Non-Federal land	Mile	170	---	52,200	52,200
Federal	Mile	30	15,400	---	15,400
Stock-water developments					
Non-Federal land	No.	82	---	33,600	33,600
Federal land	No.	48	14,800	---	14,800
Range reseeding					
Non-Federal land	Acre	11,500	---	66,900	66,900
Federal land	Acre	7,000	30,100	---	30,100
Technical services, open land	--	---	193,600	---	193,600
Educational assistance	--	---	7,900	7,900	15,800
Subtotal--Federal land			2,411,200	---	2,411,200
Subtotal--Non-Federal land			461,600	756,300	1,217,900
Total			2,872,800	756,300	3,629,100

that may be provided at the time of program installation will help landowners and operators in installing the program.

The estimated annual cost of operating and maintaining these measures is $253,400. Of this amount, it is estimated that the Federal Government will expend $104,100 on Federal land and $49,000 on non-Federal land, and that local interests will expend $100,300 on non-Federal land.

BENEFITS FROM THE RECOMMENDED PROGRAM

The following discussion and benefit determinations have been made on the assumption that the Santa Maria Project will be installed. The benefits shown are over and above those attributable to the Project.

Physical Effects. The combined effects of all the measures will reduce excessive surface runoff and promote increased infiltration of rainfall into the soil and rock strata. The frequency and magnitude of damaging floods will be reduced materially by the program. When the Santa Maria Project is installed the program will more than double the life of Vaquero Reservoir by reducing the rate of expected future sediment production.

The program will also help maintain channel capacity by reducing sediment production from the uncontrolled Sisquoc tributary. Likewise, it will help maintain high percolation rates in ground-water recharge areas by reducing the amount of surface sealing silts, ashes, etc.

Other benefits accruing from the program will be conservation of valuable crop and range land, maintenance of agricultural yields, increased farm and ranch income, reduced property loss from fire, and reduced fire suppression costs.

Monetary Benefits. Monetary benefits represent the difference between expected future flood damages plus farm and ranch income with and without the recommended program. Future flood damages are expected to increase unless a remedial program is installed. Total annual benefits, with the Santa Maria Project in operation, are about $861,300 of which $420,200 result from flood damage and sediment reductions and $441,100 are conservation and other incidental benefits (Table 4).

Additional benefits which were not used in justification of the USDA program include reduction in sedimentation of the improved channel, protection of percolation beds against sediment and debris, maintenance of yields of usable water, enhancement of recreational values, and improvement of streamflow conditions for fish life. Maintenance of crop yields on dry land and improvement in grazing capacities of rangeland will help in protecting the income of the farmers and ranchers and will contribute to the social and economic stability of the watershed economy.

Recreation use, primarily hunting, has grown rapidly in the past years. This trend will increase with population growth and increase of leisure time. The proposed fire and rangeland measures will help to raise the recreational values of the watershed.

Improvement of rainwater infiltration on the watershed land will be beneficial to streamflow and to the water supply in the underground basins.

Table 4

ESTIMATED AVERAGE ANNUAL MONETARY BENEFITS
Santa Maria River Watershed
(Long-term projected prices)

Source	Average annual benefits With Santa Maria Project
	Dollars
Floodwater and associated sediment damage reduction 1/	28,200
Indirect damage reduction	7,100
Sediment reduction (Vaquero Reservoir)	384,900
Conservation benefits	
Cropland	335,100
Range	27,600
Reduced fire suppression costs	60,200
Reduction of property loss by fire	18,200
Total program benefits 2/	861,300

1/ In areas unaffected by the Santa Maria Project.

2/ The estimated annual benefit of $55,000 expected from sediment reductions in the Santa Maria channel is not included because physical data were available for evaluation of only part of this sediment-reduction benefit.

COMPARISON OF BENEFITS AND COSTS

The ratio of the estimated average annual monetary benefit of $861,300 (with Santa Maria project) to the estimated average annual value of the total cost of $406,300 of the recommended program is 2.12 to 1.0. This ratio has been computed on the basis of long-term projected prices.

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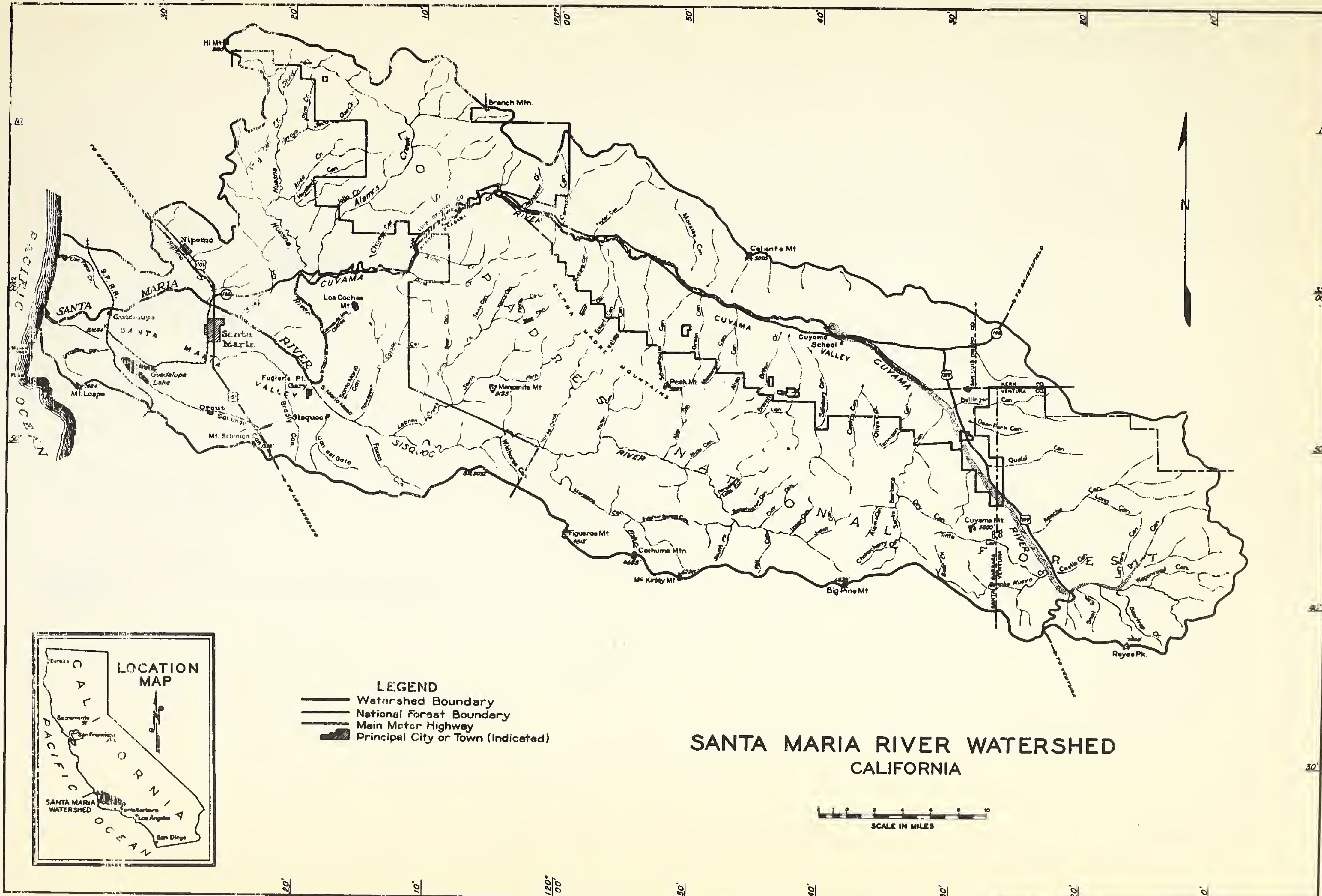
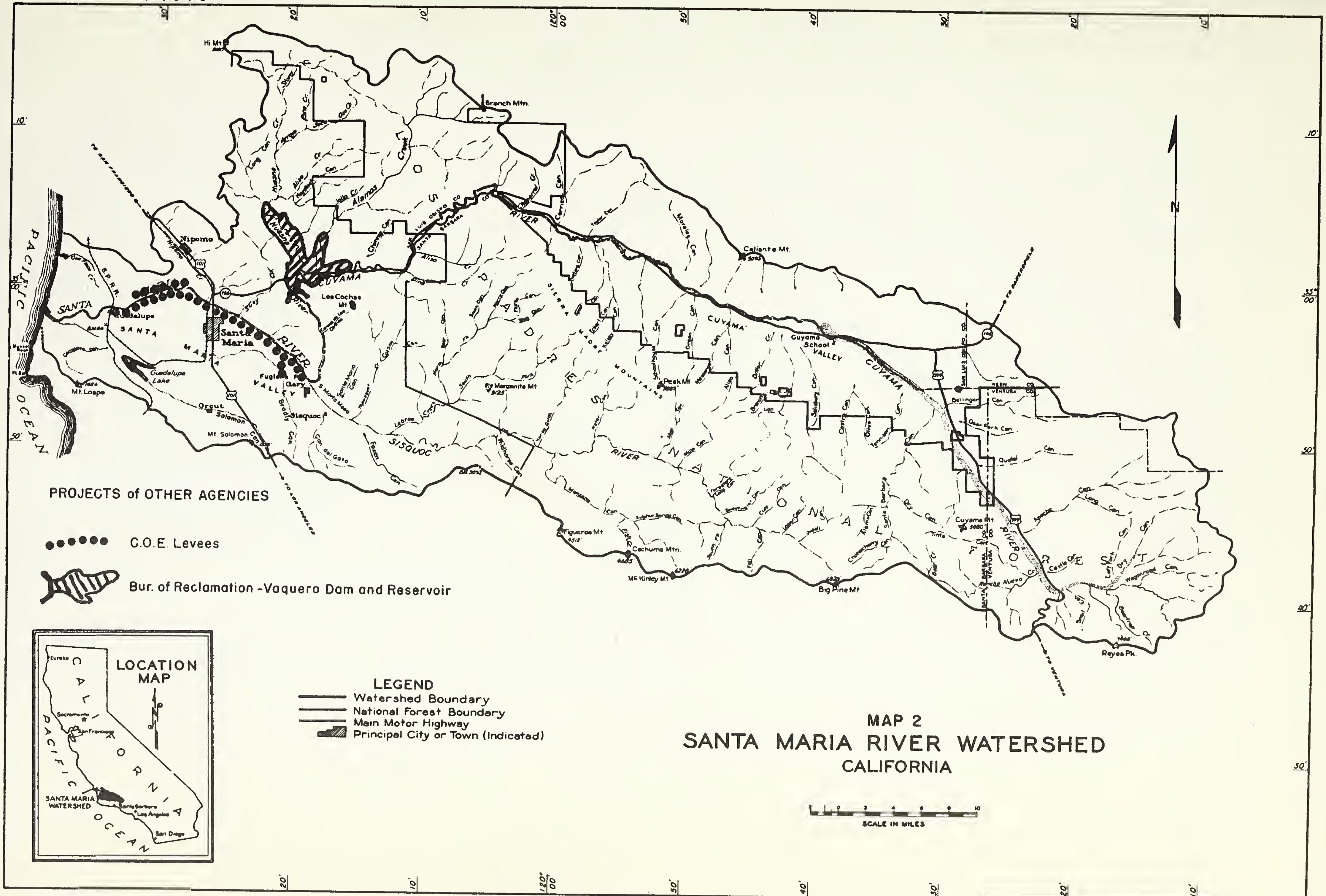


BASE - U.S.F.S. ADMINISTRATIVE MAP & U.S.G.S. 1:125000 SCALE

AGR-SCS-PORTLAND, ORE JULY 1953

7-N-14178

U.S. DEPARTMENT OF AGRICULTURE



MAP 2
SANTA MARIA RIVER WATERSHED
CALIFORNIA

BASE - U.S.F.S. ADMINISTRATIVE MAP & U.S.G.S. 1:125000 SCALE

7-N-14178-L

Report of survey

SANTA MARIA RIVER WATERSHED

California

APPENDICES

Program for runoff and waterflow retardation and soil erosion prevention for flood control purposes

U.S.DEPARTMENT OF AGRICULTURE

AGR-SCS-PORTLAND,ORE JULY 1953

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SANTA MARIA RIVER WATERSHED

Addendum - Appendix

Due to changes in Departmental policy regarding flood-prevention surveys and to the Department's recognition of the Interior and Army programs, it was necessary to make certain revisions in material previously prepared for the Santa Maria watershed appendices and report.

In order to expedite the revision of the report, changes have been made which supersede some of the data contained in the appendices. The major changes required were the conversion from 1947 prices to long-term projected prices, the presentation of all proposed programs in the form of total needs rather than just the accelerated portion, and provision for the evaluation of the effectiveness of the program in reducing runoff and sediment production. A comparison of the following tables from the report with comparative data in the appendices indicates revisions and adjustments made in the report.

Table 1, report, and Table 5, Appendix 4. The tables in the appendix are shown on the basis of 1947 prices, while Table 1 of the report is on the basis of long-term projected prices.

Table 2. The flood-prevention measures (A Measures) were extracted from the data in Appendix 5 where no separation was made for A and B measures. Acquisition of private land by public agencies was eliminated and all other costs were adjusted to long-term projected prices. Where the appendix material showed only the accelerated programs, further adjustment was made to reflect total needs.

ESTIMATED COST OF INSTALLING FLOOD-PREVENTION MEASURES
(A Measures)
Santa Maria River Watershed
(Long-term projected prices)

Measures 1/	Unit	Quantity	Cost: Federal 2/	Cost: Non-Federal Public	Cost: Private	Cost: Total
			Dollars	Dollars	Dollars	Dollars
Stabilizing and sediment control structures	No.	90	366,800	-	122,300	489,100
Subwatershed waterway improvement	Mile	27	74,000	-	49,200	123,200
Stream channel improvement	Mile	13	274,700	-	147,900	422,600
Diversion ditches and dikes	Mile	55	55,700	-	37,200	92,900
			771,200	-	356,600	1,127,800

1/ All measures are on private land.

2/ Includes cost of collecting basic data needed for guiding program installation and operation, and for testing effectiveness of the program.

ESTIMATED COST OF INSTALLING LAND-TREATMENT MEASURES
(B Measures)
Santa Maria River Watershed
(Long-term projected prices)

Measures	Unit	Quantity	Cost			
			Federal	Non-Federal Public	Private	Total
			Dollars	Dollars	Dollars	Dollars
Terrace systems including outlets						
Non-Federal land	Mile	50	-	-	3,900	3,900
Establishment of annual winter cover crops						
Non-Federal land	Acre	5,000	-	-	23,000	23,000
Establishment of permanent cover						
Non-Federal land	Acre	8,500	-	-	78,200	78,200
Farm Ponds						
Non-Federal land	No.	40	-	-	82,400	82,400
Contour and cross slope strip cropping						
Non-Federal land	Acre	2,000	-	-	18,000	18,000
Crop residue utilization						
Non-Federal land	Acre	62,000	-	-	111,600	111,600
Subsoiling						
Non-Federal land	Acre	35,000	-	-	11,300	11,300
Protected outlets						
Non-Federal land	No.	200	-	-	7,200	7,200
Cooperative forest fire control						
Non-Federal land	Acre	422,000	260,100	260,100	-	520,200
Fire control						
Federal land	Acre	652,000	2,350,900	-	-	2,350,900

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ESTIMATED COST OF INSTALLING LAND-TREATMENT MEASURES (Continued)

Measures	Unit	Quantity	Cost			
			Federal	Non-Federal Public	Private	Total
			Dollars	Dollars	Dollars	Dollars
Fencing						
Non-Federal land	Mile	170	-	-	52,200	52,200
Federal land	Mile	30	15,400	-	-	15,400
Stock-water developments						
Non-Federal land	No.	82	-	-	33,600	33,600
Federal land	No.	48	14,800	-	-	14,800
Range reseeding						
Non-Federal land	Acre	11,500	-	-	66,900	66,900
Federal land	Acre	7,000	30,100	-	-	30,100
Technical services, open land	-	-	193,600	-	-	193,600
Educational assistance	-	-	7,900	7,900	-	15,800
Subtotal - Federal land			2,411,200	-	-	2,411,200
Subtotal - Non-Federal land			461,600	268,000	488,300	1,217,900
Total			2,872,800	268,000	488,300	3,629,100

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 1

PHYSICAL FACTORS

Santa Maria River Watershed, California

To accompany report on survey, flood control,
Santa Maria River Watershed, California, dated June 1950

APPENDIX 1

PHYSICAL FACTORS

Santa Maria Watershed, California

Physiography

The watershed is divided into three natural subunits. The westerly unit consists of the broad Santa Maria Valley, a highly developed agricultural area of flat alluvial materials bounded on the north and south by low, grass-covered foothills, and on the west by the Pacific Ocean. It comprises about one-eighth of the total watershed area.

The remainder of the watershed is divided diagonally into two areas by the Sierra Madre Mountains, which have a maximum elevation of 5,800 feet at Peak Mountain.

The northern of these two areas is the Cuyama River basin, which comprises about three-fifths of the watershed. About 10 percent of the Cuyama basin is relatively flat and, except for some bodies of riverwash, is suitable for cultivation. It lies at an elevation of about 2,000 feet. The rest of the Cuyama drainage basin is rough and mountainous. A considerable portion on the north side of the river is semi-barren, and is known locally as the "Cuyama Badlands."

The Cuyama River is about 108 miles long. The upper 12 miles have an average gradient of 48 feet per 1,000, and the lower 96 miles have an average of 10 feet per 1,000.

On the eastern edge of the Cuyama River basin, the mountains rise to over 8,500 feet, the highest elevation in the watershed.

South of the Sierra Madre Mountains is the Sisquoc River drainage basin. The river has a total length of about 50 miles, and an average grade of about 25 feet per 1,000. No extensive agricultural land exists in this area, almost all of which is within Los Padres National Forest. The country through which the Sisquoc flows is mountainous, brush-covered, and practically inaccessible except on foot or horseback.

Climate

Due to the variation in elevation and distance from the ocean, the climate of the Santa Maria watershed varies considerably.

The western valley and adjacent foothills have a climate tempered by the close proximity of the ocean which is characterized by cool, foggy summers. The mean temperature for the three hottest months--July, August, and September--is 64° F., and the highest temperature recorded is 100° F. The average for the coldest month--January--is 52° F., and the lowest temperature recorded is 23° F. Extreme temperatures are

rare and of short duration. The western valley being open to the ocean receives the full force of the west and northwest winds which are prevalent throughout the spring and summer months.

By contrast, the balance of the watershed lies behind the barrier of the Sierra Madre Range, and thus is characterized by greater extremes of temperature. Fogs are infrequent in the upper valley, and the summers are very hot and dry. In the rainy winter season, the mountainous areas are very cold with snow up to 10 feet in depth at higher elevations.

The rainy season throughout the watershed extends from October to April, with the mean annual rainfall of 14 inches, as reported by the Weather Bureau, at Santa Maria.

The Weather Bureau, U. S. Department of Commerce, has collected climatological data on temperature and precipitation at Santa Maria for 49 years. This is the only climatological station in the Santa Maria drainage area.

Table 1 shows the mean monthly climatological data for Santa Maria, based on 49 years of record.

Table 1.--Mean monthly climatological data, 1891-1940, Santa Maria, California

Month	Mean temperature	Mean precipitation	Distribution of annual precipitation
	Degrees F.	Inches	Percent
January	50.0	3.32	23.95
February	51.4	2.75	19.84
March	53.6	2.53	18.25
April	55.7	0.87	6.28
May	58.8	0.54	3.90
June	61.7	0.02	0.15
July	63.6	.00	.00
August	63.9	0.06	0.44
September	63.2	0.24	1.73
October	61.3	0.61	4.40
November	56.8	1.04	7.50
December	52.4	1.88	13.56
Annual	57.7	13.86	100.00

Land Cover

Specific information on the extent and distribution of cover types was needed as basic data for investigations undertaken by the survey. The determination of the areal extent of the minimum infiltration complexes and subcomplexes used in the analysis of streamflow was based in part on the major cover types.

Natural cover areas in the watershed were segregated into the seven types, grass-open woodland, sagebrush, chaparral, oak woodland, mixed conifer, pinon-juniper, and semibarren. Agricultural areas were classified as either irrigated or nonirrigated. Each broad land cover type is tabulated by area in table 2 and a general description of each type follows:

Grass-Open Woodland.--Grass and open woodland is the predominant type at the lower elevations, but also is found on open ridge tops, or potreros at elevations up to 5,000 feet. This type is extensive, occupying an area of 230,000 acres (table 2). Mean annual precipitation varies between 10-20 inches, except at the higher elevations where it reaches about 25 inches.

The effectiveness of this type in retarding runoff and reducing erosion is dependent largely on the intensity of range use. Grazing during the wet winter period significantly reduces infiltration capacity.

Sagebrush.--The sagebrush type occupies an area of 115,970 acres in the watershed (table 2). A high proportion, upward of 80 percent, of the vegetation consists of shrub or woody species of sagebrush, sage, buckwheat, and Yucca. Grassland herbs frequently form up to 20 percent of the cover. The type is quite variable in the watershed, and three subtypes are recognized.

At the lower elevations, grass or herbaceous vegetation composes the understory and resembles in a number of respects the grass-open woodland type. It forms about 80 percent of the total type area.

The second variation of the sagebrush type recognized is composed principally of Yucca with scattered sagebrush and annuals. It occupies an area of 5,000 acres on the steeper slopes, at elevations of 1,000 to 2,500 feet. Approximately one-half of this subtype is found on the poor sites, such as talus slopes, the remainder evidently representing a regression from a higher type due to repeated burning. The effect of this cover on erosion and runoff is apparently slight.

The third variation is at higher elevations where the sagebrush type is dense. The cover here is composed of sage and buckwheat species for the most part. Grasses and herbs are usually absent, and the litter is light. Ordinarily erosion is accelerated and runoff excessive.

Table 2.--Land cover, Santa Maria River watershed, California, 1947

Type	Cuyama watershed	Sisquoc watershed	Santa Maria Valley	Total
	Acres	Acres	Acres	Acres
Natural cover				
Grass-open woodland	165,810	31,490	32,800	230,100
Sagebrush	73,740	24,380	17,850	115,970
Chaparral	178,080	201,140	2,150	381,370
Oak woodland	34,060	29,390	8,250	71,700
Mixed conifer	14,230	4,790	240	19,260
Pinon-juniper	113,630	12,870	0	126,500
Semibarren	122,000	680	6,850	129,530
Cultivated				
Irrigated	3,120	2,050	36,660	41,830
Nonirrigated	25,640	11,040	45,780	82,460
Total	730,310	317,830	150,580	1,198,720

Chaparral.--The chaparral type which combines all areas of chamise and chaparral, with the exception of sparse semidesert chaparral, occupies an area of 381,370 acres. It is confined to the rough mountainous portion of the watershed. It is composed primarily of shrub species of oak, ceanothus, manzanita, mountain mahogany, chamise, Christmas berry, and holly leaf cherry.

Over 26,000 acres, or approximately 7 percent of the chaparral type is composed of nearly pure chamise. Chamise also occurs scattered throughout the chaparral type, principally on poor or deteriorated sites mostly on south slopes, but occasionally on north slopes which have been subjected to repeated burning. An example of the latter is on the north slopes of the Sierra Madre Mountains above the Cuyama Valley. The subtype ordinarily is not so dense as the chaparral and the litter is light even under old stands.

Old-growth chaparral forms a very dense, impenetrable cover 6 to 15 feet in height with a heavy ground litter, often over 3 inches in depth. Mature chaparral is as effective as the oak woodland and mixed conifer types in reducing erosion to negligible rates and retarding runoff by increasing percolation. Most of the chaparral in the Santa Maria River watershed is rather young in age due to past fires, and has not formed a complete cover, particularly on south slopes.

Oak Woodland.--The oak-woodland type covers an area of 71,700 acres. The type is confined primarily to canyon bottoms and small patches on north slopes. Species of oak, sycamore, willow, poplar, alder, and maple, and in addition digger pine are the principal species found in the natural type. Eucalyptus species form the plantations. Sagebrush and chaparral species are found abundantly in some areas, possibly as the result of past fires. Usually a light understory of annual grasses and herbs is present. Oak-woodland areas not burned in recent years have developed a heavy leaf litter which is effective in retarding runoff.

Mixed Conifer.--Coniferous stands in this watershed are limited to the ridge tops, and a few canyons above 3,500 feet in elevation. The present area of this type is 19,260 acres. Formerly the area was much more extensive, but fires have limited the type to its present size. Needle litter is usually heavy.

The coniferous species are coulter pine, ponderosa pine, Jeffrey pine, sugar pine, bishop pine, white fir, bigcone spruce, and incense cedar. Chaparral and woodland species often form a scattered understory, especially on north slopes.

The contribution of the mixed conifer type area to the flood problem is of little significance.

Pinon-juniper.--This type occupies an area of 126,500 acres and is limited to the drier inland slopes of the Sierra Madre Mountains, the Caliente range, and the upper Cuyama drainage basin. The principal species are pinon pine, juniper, and species of oak and mountain mahogany. Grasses and herbs are commonly associated as an understory, with foxtail chess, and alfileria predominating. Litter is variable in depth and usually light.

Semibarren.--This type is common to the Caliente and Cuyama Badlands, with scattered areas on the north slopes of the Sierra Madre Mountains. Stream channels, coastal sand dunes, and urban areas are also included in the type. The area is slightly greater than the pinon-juniper type, occupying 129,530 acres. More than 50 percent of the type is barren. The principal species are similar to the pinon-juniper and sagebrush types. Litter is practically nonexistent, except immediately under the vegetation.

Irrigated Crops.--Irrigated sod and row crops are confined to the Santa Maria Valley, with the exception of 3,120 acres in the Cuyama Valley, and a very small area in the Huasna Valley. The irrigated land is confined to the flat valley floor. The predominant crop in the Cuyama Valley is potatoes. Lettuce, cauliflower, sugar beets, alfalfa, broccoli, celery, tomatoes, flower seed, and miscellaneous vegetables are included among the irrigated crops in the Santa Maria Valley. In the Cuyama Valley, the production of potatoes and sugar beets under irrigation is a recent development.

Nonirrigated Crops.--Generally, nonirrigated crops are found in the mesa lands surrounding the Santa Maria Valley, in the valley bottoms, and on adjacent low foothill slopes of the Huasna Valley and in the Cuyama Valley. The principal crops grown are wheat, grain, hay, barley, and beans.

Geology and Soils

The topography of the Santa Maria watershed reflects the geologic history of the drainage basin. The two principal mountain ranges, the Sierra Madre and San Rafael, have been formed by uplift which arched the sedimentary beds, breaking them along the faults to form the Cuyama and Sisquoc Rivers. Subsequent stream cutting and erosion have carved a steep, rugged topography capable of yielding high erosion rates and rapid storm runoff. The nonmountainous portions of the watershed--the Cuyama and Santa Maria Valleys--are structural down-folded basins filled to depths of several thousand feet with clay, sand, and gravel by the streams discharging into the valleys.

Similarly, geology has had a direct influence on the soils of the watershed. The soils of the two great valleys, the Cuyama and the Santa Maria, are predominantly alluvial of sedimentary origin. Infiltration capacities are good except where certain farming practices have compacted the soil. Erosion in the valleys is not a serious hazard except for bank cutting along the rivers. Overlaying the Quaternary terraces above the floor of these two valleys are large areas of soils derived from the coastal plain and old valley-filling deposits which vary in texture and erodibility. The light-textured soils are highly erodible, particularly under cultivation.

In the Bradley Canyon area some 2,870 acres of moderately to well developed æolian soils occupy the Quaternary terraces. Past cultivation has resulted in the abandonment of more than 350 acres as the result of severe sheet and gully erosion.

The soils of the Caliente, Sierra Madre, and San Rafael Mountains are predominantly residual on moderately or well consolidated sediments. Under the stabilizing influence of undisturbed natural cover a good soil depth has developed. Depletion of the cover either by fire or excessive grazing has been accompanied by high erosion rates and accelerated storm runoff.

The soils of the "Cuyama Badlands" in the northeast corner of the watershed are also residual but developed from poorly consolidated silt beds and coarser sands which erode easily.

The relation of underlying rock to soil type and the approximate hydrologic properties of soils are shown in more detail by the following table.

Table 3.--Relation of underlying rock to soil texture and approximate hydrologic properties of soils, Santa Maria watershed

Underlying rock	Soil texture	Porosity 1/	Specific retention 2/	Specific yield 3/
		Percent	Percent	Percent
Shale				
Limestone	Loam	45-50	35 ±	15 ±
Basalt	Clay loam	45-50	35 ±	10 ±
Serpentine	Clay	50-60	50 ±	0-5
Sandstone				
Conglomerate	Sandy loams	35-40	15 ±	20 ±
Crystalline igneous rocks	Rocky soils	35	10 ±	25 ±

1/ Porosity is percentage of total volume occupied by interstices.

2/ Specific retention is ratio of volume of water a soil will retain against the pull of gravity to its own volume.

3/ Specific yield is ratio of volume of water a soil will yield by gravity to its own volume.

On the basis of general soil characteristics and conditions of lithology, all parts of the watershed have been classified in accordance with the following groups. It is emphasized that each area delineated doubtless includes local variables that are not discussed in the brief descriptions.

Residual Soils and Poorly Consolidated Sediments.--This group is confined to the Cuyama Badlands, a large area in the eastern end of the watershed. Over a good portion there is no soil but only exposures of the soft sediments. Where soil exists it is generally gray, low in organic matter, and without profile development. The texture is predominantly light, but there are small areas of medium and heavy soil. Lime is found intermittently.

The sediments are of Tertiary age and are non-marine. They consist of

poorly consolidated and easily eroded clayey sands. The area is characterized by steep slopes; in many places the sediments have been eroded to an organ-pipe pattern which, particularly where the strata are vividly colored, present a spectacular picture.

Testimony to the extreme erosion rates is afforded by the suspended load samples taken in streams draining this area. Twelve samples averaged 147,500 parts per million.

Residual Soils on Moderately or Well Consolidated Sediments.--About half of the watershed falls in this category. Covering such a large area, it is to be expected that it will embrace a variety of conditions.

In general, under chaparral or woodland cover, the soils are of good depth, are moderately well supplied with organic matter, and have little or no profile development. Textures are generally medium or light, although in the eastern part of the Sierra Madre Mountains there is an extensive area of heavy-textured brush-covered soils. They faithfully reflect the character of the underlying rock in most instances.

Under grass cover the soils are generally either heavy-textured or too shallow to support brush.

At the base of the Caliente Mountains a body of Quaternary terrace material is included because it is so badly dissected that the steep slopes are of greater importance than the remnants of the terrace top.

Many stringers of alluvial soil in canyon bottoms are included because they are too small to map. Similarly, several areas of rock outcrop, too small to map, occur in the Sisquoc basin.

Erosion conditions vary with cover, texture, and slope. Many parts of the area, particularly where textures are light or medium, and the depth is not great, are subject to severe erosion when denuded. The soils with heavy textures generally have not suffered from erosion except in the southwest edge of the watershed where gullying has been severe. Landslips, however, do occur more frequently on these soils.

Rocks underlying these soils are Cretaceous and Tertiary marine formations, consisting of sandstone, shale, and conglomerate. The weathering and erosion of these rocks form the major portion of alluvium in the Cuyama and Santa Maria Valleys.

Residual Soils and Metamorphic and Volcanic Rocks.--Soils developed on metamorphic and volcanic rocks are quite similar in this watershed. They are almost invariably heavy textured and are well supplied with organic matter. These soils are shallow near the few zones of rock outcrop, but otherwisethey are of good depth. Colors range from red to black.

Erodibility is low because of the cohesion of the heavy textured material and the customary density of the cover. At the beginning of

the rainy season these soils generally are cracked deeply and therefore permit the absorption of large quantities of water. Later, when the colloids swell, the infiltration capacity is reduced, but the total storage capacity remains high. These soils drain slowly and runoff would be large from storms that were closely spaced. A tendency toward landslips has been noted locally.

The rocks consist predominantly of argillaceous shale, serpentine, and jasper of the Franciscan formation, which is Jurassic (?) in age. There are also small bodies of basalt diabase.

Residual Soils on Granitic Rocks.--The only granitic rock found in place in the Sawmill Mountain block in the eastern extremity of the watershed, where dull brownish gray, highly micaceous, sandy-loam soil occurs in this formation. There is little or no profile development, and a good supply of organic matter is present in the surface layer. The soil mantle averages about 18 inches in depth, but it rests upon disintegrated and shattered granite that is capable of absorbing and storing large quantities of water.

Erodibility is low, partly because of the ability of the soil mantle to absorb moisture and partly because of the interlocking of the angular soil particles.

Moderately or Well Developed Aeolian Soils on Quaternary Terraces.--The vicinity of Bradley Canyon includes all of the developed soils that are unquestionably deposited by wind. These belong to the Garey series, which is characterized by a moderate degree of profile development, and the Tangair series, which has a cemented hardpan and sometimes a claypan as well. Both series are generally low in organic matter and fertility, and are highly erodible. The dominant texture is fine, sandy loam.

The Garey soil is highly susceptible to gully erosion. The occurrence of many vertical-walled gullies, 20 feet or more deep, has already resulted in the destruction of about 350 acres of arable land. Sheet erosion is active, too, but its effects are less noticeable because the difference in fertility between surface soil and subsoil is less apparent in Garey series.

Gullying in the Tangair soil is active, but is not as rapid as in the Garey due to the presence of a hardpan which limits the depth of gully cutting. Sheet erosion has exposed the hardpan or claypan in some places.

Nonaeolian Soils on Quaternary Terraces.--A wide range of soil conditions is encountered on the terraces. The most common soil is one with a light or medium-textured surface, a clay or sandy-clay subsoil, and a substratum of heavy river gravel.

In the vicinity of Betteravia the soil is light-textured and has a firmly cemented hardpan which, over an area of some 20 acres, has been exposed by removal of the surface soil. It appears that wind and water have

both been active in soil formation and in its destruction.

Terraces along the south side of the Cuyama Valley are dissected by drainage channels of fairly normal appearance over part of the area mapped, and unmapped stringers of alluvial soils exist. In places along the southern edge of the boundary alluvial and colluvial material from the Sierra Madre mountain mass has modified or buried the developed terrace soil. The sites are not readily accessible and the relations have not been thoroughly worked out.

The terrace at the head of Apache Canyon consists of outwash from the Sawmill Mountain granitic block. The soil is coarse and stony, has little or no profile development, and is unsuited to cultivation.

In general, the elevated position of the terraces causes a high gully hazard. Increased runoff, due to cultivation or some other cause, forms channels at the terrace edge, working back rapidly into the terrace top and eventually destroying the arable land. Normally these soils are of the more erodible types.

Sand Dunes and Recent Aeolian Soils.--The recent aeolian soils, with the exception of the area east of the mouth of Nipomo Creek are low in fertility and light in texture.

Within about four miles of the ocean the material is too raw to be called a soil and must be classed as dune sand. A large part of the dune area has insufficient cover for stabilization and is moved very readily by wind. A small area between Caralillos Creek and the mouth of the Santa Maria River is under cultivation, although yields are low and the erosional damage is great.

Sand dunes occupy an area immediately adjacent to the coast. The area is about 8,400 acres in size, eight miles long and three and one-half miles wide at the point of greatest width. The dune areas are not encroaching upon agricultural land. It is the custom to leave a strip of native cover between dune areas and cultivated land.

Elsewhere vegetal cover has been established naturally for sufficient time to permit an accumulation of organic matter in the surface soil and occasionally a slight accumulation of colloidal material in the subsoil. Where this occurs the soil has been classified in the Oakley series. Very little of it is cultivated because yields are too low. Where a good cover exists, infiltration is high and there is no appreciable erosion. The greatest erosion hazard exists north of the Santa Maria River where cultivation close to the edge of an escarpment has resulted in severe gullying.

Alluvial Soils, Chiefly Without Profile Development.--Most of the alluvial soils in the Santa Maria Valley belong to the Yolo series, one of the best agricultural soils in the State. It is a recent alluvial soil derived mainly from materials of sedimentary origin. Some bodies of Dublin soils and a considerable area of riverwash are included.

Slopes are slight and infiltration capacities are good except where certain farming practices have caused compaction. Erosion is not a serious hazard except for bank cutting along the rivers.

In the Cuyama Valley no detailed soil survey has been conducted. However, it is known that most of the soils mapped in this group are derived from sedimentary materials and range from soils having no profile development to those having a slight colloid accumulation in the subsoil. Most of these soils are highly calcareous, and some areas are seriously affected by alkali. Riverwash along the Cuyama River is included in the group. Slopes range a little higher than in the Santa Maria Valley, and erosion is a little more noticeable. Almost every winter there is a small acreage lost by bank caving, and when this occurs, it is a total loss because the stream banks are 10 to 30 feet high for most of the length of the valley.

Many narrow stringers of recent alluvial soils, too small to be mapped are found along streams.

The effect of these physical factors--topography, climate, vegetative cover, geology, and soils--on runoff, erosion, and sedimentation is analysed in Appendix 3.

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 2

LAND AND WATER ECONOMY

Santa Maria Watershed, California

To accompany report on survey, flood control,
Santa Maria Watershed, California, dated June 1950

APPENDIX 2

LAND AND WATER ECONOMY

Santa Maria Watershed, California

Land Economy

Flood and conservation problems are the consequence of man's encroachment upon a natural flood plain, and the conversion of watersheds to some useful purpose. The past balance between the river plain and its source is destroyed. Cities, roads, and bridges are built, land is taken under cultivation in areas which constitute the course of the river during high flows. Hillsides are taken under the plow, mountain grasslands stocked heavily with cattle or sheep, and forest areas are used for recreation. Erosion caused by improper cultivation or overgrazing, and unnecessary forest fires started by carelessness all contribute to the natural hazards of life on the flood plains.

History of Economic Development.--Agricultural development of the Santa Maria River watershed began between 1837 and 1844 when large land grants were made by the Mexican Government. Livestock production became the principal industry, and the indications are that stocking of the range became heavy even during the early periods of development.

American occupation began about 1867 following a period of severe drought which caused the cattle industry to decline. Grain growing soon developed into an important industry, and fruit production and bean growing were introduced, but cattle raising still continued as an important industry since a major part of the watershed is suitable for grazing.

By 1900 fruit production began to decline, due chiefly to unfavorable climatic factors, such as wind, fog, and cool weather. Until the construction of the Southern Pacific Railroad in 1901 through the lower end of the watershed, much of the grain and beans were shipped by boat from Point Sal on the coast southwest of Santa Maria, and later via a narrow gauge railroad to Port Hartford near San Luis Obispo, and from there by boat to Los Angeles and San Francisco markets.

Irrigation was introduced in 1897 when the Union Sugar Company began growing beets near Betteravia, but extension of the irrigated area was slow until 1920. During the 1920's there were numerous shifts on the valley lands from beans and grain to vegetable and flower seed crops, which continue to be the major land use in the Santa Maria Valley. These shifts have been facilitated by the availability of an ample supply of inexpensive, efficient farm labor, largely Filipino and Oriental.

Irrigation by means of pumping from wells is practiced extensively on the valley cropland. In late years the apparent lowering of the water table has been of concern particularly in the area east of Santa Maria, and in 1937 a water conservation district was organized with the objective of developing plans for water conservation and flood control in the Santa Maria Valley.

About 1902 oil was discovered along the south side of the valley. The development of this new industry was spasmodic, but nevertheless progressive, and at present is an important industry.

The growth of urban centers is associated with the agricultural development, and has been fairly rapid since 1900. Guadalupe, founded in 1870 was the earliest and largest settlement until after American occupation, following which Santa Maria (first called Central City in 1872), Sisquoc, and Gary were founded. Orcutt, an oil center town, was founded following the discovery of oil in 1902.

The watershed is traversed by the principal north-to-south coastal highway (U. S. 101), and by Maricopa Road (U. S. 399) which connects Santa Maria with the interior San Joaquin Valley. All main roads in the valley are hard surfaced, but the mountainous portion of the watershed is only accessible via dirt roads or trails.

Effects of Floods on Development.--Periodic large discharges have caused great destruction and impairment of agricultural land through bank erosion. No appreciable new land has been formed along the river by sedimentation and thus there has occurred a permanent reduction in the land resources of the watershed.

There are about 51,781 acres of level land in the Santa Maria Valley, 10,000 acres of which are now river wash. While channel shifting during high flows has decreased the amount of productive land, very little overbank flooding has been evidenced in the last 50 years.

Agricultural activity is at about the same level of intensity on most of the land subject to overflow as on adjacent land of similar natural and environmental characteristics.

Recurring flooding from local waters has exerted a slight influence on the location of urban development at Santa Maria, but probably has not affected the gross amount of such development. Development and settlement north of Santa Maria in the area overflowed by large floods prior to 1910, appears to be proceeding without regard to any flood hazard. Urban and suburban development, both residential and commercial, has increased materially since 1937.

Effects of Erosion on Development.--The development of agriculture in parts of the watershed has been accompanied by an acceleration of soil erosion, particularly on cultivated land. Barley, oats, and wheat, and in many instances, beans have been planted on erodible sloping land which originally was moderately productive, but has since seriously deteriorated by accelerated erosion. The amount of this land is only a small percentage of the watershed total, and cultivation or abandonment does not greatly affect the total production of the area. Some of the more depleted tracts have already been retired, and it appears that ultimately most of the more steeply-sloping erodible land must return to grassland or woodland use.

Population Affected by Floods and Erosion.--In 1940, about 13,400 people in the Santa Maria Valley were living in the flood-hazard zone. The probable maximum flood may take a course affecting a large proportion of the number directly, and all of them indirectly. Damage would be caused to the largest number of people if the probable maximum flood flowed through the city of Santa Maria. The probable maximum discharge from Bradley Canyon would cause damage to or otherwise affect directly more than half of the population of the city of Santa Maria, in addition to a small number of rural residents living in the overflow area. The number of people affected by flood flows in the minor damage areas is relatively small. However, it is conceivable that all these would also be affected by the probable maximum flood of the Santa Maria River.

Erosion during periods of heavy rainfall affects more or less the whole of the farming population, although approximately one-third of the people living in the South Mesa area are affected by the most detrimental erosion damage.

Land Ownership.--The ownership of land has been classed as Federal, State, and private. The Federal land comprises national forest and public domain, and accounts for 54.4 percent of all the land in the watershed. State land is either tax deeded or school land, and amounts to 0.7 percent, while private land makes up 44.9 percent.

As may be seen from table 1, 39,325 acres of private land are within the national forest boundary, and as such add to the problem of protecting the watershed from fires.

Table 1.--Land ownership, Santa Maria River watershed, California, 1947

Sub-watershed	Federal land: National forest	Federal land: Public domain	State land: Tax deeded	State land: School	Private land: Within national forest boundary	Private land: All other 1/	Total
	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Cuyama	370,595	59,450	3,968	317	34,145	261,835	730,310
Sisquoc	221,300	990	1,960	1,320	5,180	87,080	317,830
Santa Maria Valley	0	160	142	0	--	150,278	150,580
Total	591,895	60,600	2/6,070	3/1,637	39,325	499,193	1,198,720

1/ Includes a nominal amount of county land and State Division of Highways land.

2/ About 2,450 acres are located within the boundary of the National Forest.

3/ About 1,280 acres are located within the boundary of the National Forest, U. S. Dept. of Agric. Compiled from land ownership map, Santa Maria River Flood Control Survey.

General Land Use.--Of the total 1,198,720 acres of land in the Santa Maria River watershed, 124,290 acres, or 10.4 percent, are cropland. Irrigated cropland comprises 41,830 acres, or 3.5 percent of the total cultivated area. Not all of the irrigated acreage is so used, however, In the rotation with irrigated crops approximately 9,500 acres are devoted to dry-land crops in any one year. The acreage devoted exclusively to dry-farming constitutes 6.9 percent of the whole watershed or 82,460 acres. These lands contribute in varying degrees to erosion problems which are most acute on the south side between Foxen and Corralillas Canyons.

Total usable range in the mountains, the hills surrounding the valley, and the mesas is estimated at 39.3 percent of the total area, or 471,643 acres.

No net increase in the arable area is expected in the future, since present trends indicate that many of less desirable dry-farmed areas are gradually reverting to range and pasture, particularly on the mesas. However, a slight increase in irrigated acreage may be expected in the near future. The extent to which future irrigated areas can be maintained is problematic, and depends entirely upon the availability of additional supplies of irrigation water.

Urban developments at present occupy only an infinitesimal part of the watershed, and constitute not more than one-tenth of 1 percent. Growth of towns has been rather slow, limited largely by lack of industrial opportunities. Prior to 1946 only Orcutt and Santa Maria expanded significantly. Recent oil discoveries in the Cuyama Valley have stimulated this industry which may well influence materially the basin's urban and industrial growth.

Slightly more than 40 percent of all land in the Santa Maria drainage basin is watershed not suitable to agricultural use, and is almost exclusively restricted to the mountain region. For the greater part and where water is available, it is interspersed with usable range, and occasionally cropland. Small spots are utilized as camps for hunters and other types of recreation. The protection of these areas from devastating fires should be of greatest concern to the people of the Santa Maria Valley, as well as to the livestock producers and recreationists.

River washes, dunes, and swamps, the latter principally in the Oso Flaco district, account for 1.2 percent of the area. River washes constitute the major part, due to the extensive channel of the Cuyama River, and the broad but short Santa Maria River wash.

A breakdown of acreage in different land uses by subwatershed areas is given in table 2.

Agricultural Land Use.--The agriculture of the Santa Maria watershed is divided naturally into three major types--irrigated, dry-land, and livestock grazing. Irrigated vegetable and sugar-beet crops occupy the river valley. Bordering the valley on the mesas and the lower foothills, dry-land farming with some livestock production predominates. The hills and open mountain areas are suitable only for grazing and are used extensively for livestock production, interspersed with general crop agriculture. Irrigated potato and truck-crop growing on several thousand acres formerly used for wheat production is a recent development in the Cuyama Valley.

Size of Farms.--Total number of farm units in this area varies to some degree from year to year. This is due mainly to the way irrigated vegetable production is handled with its large degree of tenant and sharecropper operation. To a lesser extent variation in numbers is found also in the dry-land areas. Best estimates place the present numbers of farm units at 510; of these, 210 are dry-land farms including about 12 small orchards. There are 70 livestock ranches and 230 irrigated farm units. A brief description of some of the important types of farming is given below.

Dry-land Farming.-- Basically, the dry-land farms of the mesas and foothills are organized around a rotation of small white or pink beans, grain, grain hay, and fallow, with the stubble and volunteer growth of the fallow pastured. Oats are raised on the lighter soils while barley represents the principal grain crop on the heavier soils. Variations

Table 2.--Principal land uses: Santa Maria River watershed, California, 1947

Use	Subwatershed: Cuyama	Subwatershed: Sisquoc	Subwatershed: Santa Maria Valley	Subwatershed: Total	Percent of total land in watershed
	Acres	Acres	Acres	Acres	Percent
Agricultural					
Cultivated 1/					
Irrigated	3,120	2,050	36,660	41,830	3.5
Nonirrigated	25,640	11,040	45,780	82,460	6.9
Usable rangeland 1/2/	338,571	82,090	50,982	471,643	39.3
Commercial woodlots	0	0	1,300	1,300	0.1
Nonagricultural					
Urban, including industrial	0	25	1,585	1,610	0.1
Watershed 3/	252,465	221,970	7,763	482,198	40.1
Semibarren	102,744	0	325	103,069	8.8
River washes, swamps, and dunes	7,770	655	6,185	14,610	1.2
Total by areas	730,310	317,830	150,580	1,198,720	100.0

1/ Includes some land also used for production of petroleum.

2/ Includes open grassland, sagebrush, pinon-juniper, and semibarren.

3/ Includes mixed conifer, oak woodland, chamise, and chaparral; also used for recreation.

from this type of farming are found on very heavy soils, such as on the Nipomo foothills where specialty crops as winter peas and tomatoes are introduced into the rotation. Depending upon the extent of shallow soils or rought and broken land in the farm units, livestock grazing and some dairying constitute important supplemental enterprises and become the major enterprise in some instances. The land in the farming units is not always contiguous but often in scattered tracts.

In the mountain valleys different types of crops are encountered. In the Huasna Creek district, for instance, corn takes the place of beans in the rotation. Permanent pasture constitutes part of the farms, thus creating a natural basis for general farming. In contrast, the dry-land farming in the Cuyama Valley represents almost exclusively a rotation of wheat and fallow with some barley and grain hay also grown. The size of the dry-land farms of the mesas and foothills varies from less than 100 to more than 640 acres. The larger proportion of these farms is below 300 acres. For most mesa areas a unit below 300 acres is considered uneconomic and, therefore, favors exploitive farming with its accompaniment of accelerated erosion. The wheat farms of the Cuyama are several thousand acres in size.

Livestock Ranches.--Most of the livestock ranches of the mountainous and hill country produce feeder cattle or calves. Only a few fatten their own cattle. Generally some grain and grain hay is produced on the ranches to carry the cattle over the period when forage is of low nutritive value. Wheat production constitutes an important supplementary crop to livestock production in the Cuyama Valley. Although most of the mountain ranchers own some land and rent additional acreages, many depend upon the national forest and public domain for supplemental range.

The size of livestock ranches varies from several hundred to more than 50,000 acres, carrying from 20 to 2,500 head of cattle. Approximately half of the ranches are less than 3,000 acres in size. Grazing capacities or rangelands differ with location. As a general rule, the hill-land of the frontal country and the south mesa will provide forage for one grown animal on 16 to 20 acres, while on the mountain land 30 to 35 acres are needed to graze an animal throughout the year.

Present condition of most of the rangeland reflects past heavy use. This is particularly true in the Upper Cuyama where overgrazing began about 1890 and continued for more than fifty years. Once covered by perennial bunch grasses, this area now supports a sparse annual growth which, under present use, provides slight protection to the soil. Most of the range area in the basin has a moderate infiltration rate, about half an inch per hour. An exception is the Caliente Mountains area in the Upper Cuyama, which for the most part has a low rate of infiltration (less than 0.5 inch per hour). Erosion rates vary widely depending on the rainfall zone, soils, and degree of use. The most actively eroding range areas are confined to the Upper Cuyama watershed, particularly in the Caliente Mountains and Ballinger, Quatal, and Apache Canyons. Heavy range use coupled with repeated burning has reduced seriously the protective ground litter.

Irrigated Farming.--In the Santa Maria Valley intensive irrigated agriculture is practiced. Vegetables, the most important crop, are rotated with sugar beets, beans, alfalfa, and dry-land crops. In addition, some flower seed is raised. A large proportion of the land is double cropped, necessitating the extensive use of fertilizers. The type of agriculture practiced in the valley requires not only considerable seasonal labor, but also large capital outlays for machinery. Naturally, much of the cultivation is custom work. The size of the irrigated units varies from 20 to more than 600 acres, with 80 acres the most frequent size.

The irrigated area in the Cuyama Valley is devoted principally to potato raising and is farmed in large tracts. Small areas are planted to truck crops.

Value of Land.--The value of farming land on the south mesa normally varied from \$20 to \$50 per acre, while that of the Santa Maria mesa and the Nipomo foothills ranged between \$100 and \$125 per acre. Irrigated land in the Santa Maria Valley was valued in 1940 at \$200 to \$450. Rangeland in the foothills had a value of \$15 to \$25 per acre, while that of the mountain varied between \$2 to \$20 per acre with \$5 as an average. These values represent 1940 estimates. Present (1947) values have increased approximately 100 to 150 percent.

Land Tenure.--With the exception of the lands on the Nipomo foothills, most of the farming land on the mesas and the Santa Maria Valley is tenant operated. Crop share rents are common on dry-farmed land. The rent is usually one-third or one-fourth of the crop. Irrigated land is usually rented on a cash basis; the rent being paid six months in advance. The land is owned by corporations, estates, and individuals, and often in large tracts. Absentee ownership is quite prevalent.

The prevailing tenure system should not necessarily be considered the main factor in causing mismanagement of the soil on the mesas. This land is near the margin of crop agriculture, and holdings are seldom large enough to present an economic unit when converted to grazing. The fact that landlords at present can obtain a higher rent when the land is used in crop agriculture than when used as range retards this change. However, the obstacles still would be greater if the land were owner-operated.

Tax Delinquencies and Indebtedness.--The amount of tax delinquent land is insignificant. Because a large proportion of the land is owned by estates and corporations, land indebtedness is of minor importance, and may be said to have no influence on exploitive use. Operation of the irrigated land requires large crop production loans from local banks, produce companies, sugar companies, and Federal agencies.

Mining and Mineral Extraction.--Until recently mining and mineral extraction in the Santa Maria drainage were small-scale industries. Small oil fields at Orcutt, Sisquoc, and Santa Maria have been in production

for many years. A few scattered wells also had been drilled in the watershed. Small gypsum and drilling mud mines were operating in the Upper Cuyama Valley.

However, with the relatively recent discovery of the Cuyama oil field, speculative leasing and wildcat drilling have assumed boom proportions. As of May 10, 1950, the Los Padres National Forest had processed 1,769 leases including over 800,000 acres of national forest land. About 20 wells have been drilled in the Cuyama field, and producing wells indicate that the field is potentially the greatest oil discovery found in California in the past 20 years. To date no wells have been drilled in the Sisquoc, Alamo, and Huasna drainages, but large areas of private and Federal land are under lease. Needless to say, it is only a matter of time until active well drilling operations will be prosecuted in heretofore almost inaccessible back country. This activity is certain to have a very adverse effect on watershed conditions. Roads of all standards of construction will be built, hillsides and ridges will be leveled for placement of derricks, sumps, and buildings; and most detrimental of all, the probability of fire will be greatly increased.

Urban Economy.--Seven towns and villages are located in the Santa Maria watershed. Of these Santa Maria, with a population of about 11,000 (1940) is the central trading center. Due to the tenure system and the type of agriculture practiced in this area, which depends upon credit for financing the production of high-cost crops, the city is also an important local financial center. The city population derives its income predominantly from servicing the surrounding agricultural area. The only noteworthy industrial establishments are some packing sheds, ice plants, creameries, and the oil industry.

Santa Maria is located on U. S. Highway No. 101, but is not on a direct rail line. It is for this latter reason that the main packing sheds and ice plants are found 9 miles to the west in Guadalupe, located on the main Southern Pacific Railroad.

The population of Guadalupe, numbering about 1,980, finds employment in the local packing sheds, ice factories, and the surrounding agricultural enterprises.

The population of Betteravia, about 350 people, depends for work in fall and early winter on the local sugar factory, which handles most of the crop of the 5,500 acres of sugar beets grown in the valley. Additional employment is furnished during this period in a large cattle-feeding plant which utilizes byproducts of the sugar factory. When both these plants are closed, the people of this town rely upon work in the fields to supplement their part-time income.

Orcutt's population of about 500 in 1940 is largely connected with the nearby oil fields.

The other three villages are Nipomo, Sisquoc, and Gary. Nipomo's population of approximately 350 people is made up mainly of farmers and

retired farmers. Similarly, Sisquoc and Gary, with populations of 120 and 100, respectively, are inhabited by farmers and farm workers.

With large floods all communication in the valley would be interrupted. Santa Maria and Guadalupe, as well as Gary and Sisquoc, probably would be inundated. Even floods of 75,000 c.f.s. would completely isolate the city of Santa Maria from the north and east, and if coinciding with large flows from Bradley Canyon, would severely restrict communication from the south and west. To this date the flood hazard has not seriously affected the areal expansion of the town. On the contrary, development has taken place in the direction of definite hazard zones towards the river, as well as in the path of Bradley Canyon flows. A continuation of this trend would produce serious damages even with medium-sized floods.

Wildland Economy.--Eighty-seven percent, or 1,630 square miles, of the Santa Maria River watershed is composed of rough, mountainous territory of which approximately 925 square miles are in Los Padres National Forest.

This mountainous area is chiefly valuable for watershed purposes, and its secondary uses are limited to livestock grazing, and hunting, fishing, and recreation.

Approximately 139,201 acres, or 23.5 percent, of the total national forest area are used for the grazing of domestic livestock.

In accordance with the policy of maintaining the basic resources and accomplishing the highest degree of sustained use consistent with good watershed protection, the livestock numbers have been reduced from 19,862 in 1910 to 5,766 in 1940. Intensive range management practices, however, have not as yet been inaugurated.

The period of highest hunting, fishing, and recreational use occurs during the early spring, and continues through to late September. Unfortunately, the period of use coincides with the season of greatest fire danger and fire occurrence, particularly during the hunting season in August.

Although both watershed and recreational values of the mountain areas are dependent upon the maintenance of cover, the watershed value is considered the greatest since much of the underground water supply of the valley has its source in the mountains. Consequently, the recreational and hunting use during periods of high fire danger conflict with the protection policy for watershed management which has necessitated restricting the use of the national forest areas during these critical fire periods.

Destruction of the cover by fire would materially reduce the watershed value, and in addition, would cause severe debris and flood flows during the rainy season.

Fire and heavy grazing use have effected a marked change in the soil and cover conditions on both privately owned and public wildland areas. Both factors have accelerated the normal rate of erosion in many areas well in excess of present rates of soil building. The continued soil loss in the critical flood and sediment source areas has had a detrimental effect on plant recovery following fire. Slower rates of regrowth and reduced cover densities are reflected in the areas repeatedly burned or otherwise subjected to continuous heavy use.

Administration and Use of the Public Domain.--Of the present area of 652,495 acres of Federally owned land in the Santa Maria River watershed, 591,895 acres are within the boundaries of Los Padres National Forest, of which 23.5 percent is used for grazing.

Federally owned land in the unappropriated public domain amounts to about 60,600 acres, located largely in the Caliente range. Although about 27.4 percent of these lands are grazed, no grazing districts have been organized. Some tracts are leased by the Bureau of Land Management, Department of the Interior, to local residents for grazing use. Two ranchers provide most of this use. In 1941 these two users grazed a thousand or more head of cattle in the Caliente area. Other scattered parcels of unappropriated public domain generally are too precipitous or barren, or too brushy for range purposes.

The public domain lands of the Caliente mountain area have been reduced to a sparse annual cover by repeated burning and excessively heavy grazing. Long before this area was administered by the Bureau of Land Management unrestricted winter sheep grazing preceded the periodically heavy use by cattle. Extensive areas of sheet erosion characterize most of this range. Even the relatively low rainfall of this region causes excessive runoff and accelerated erosion.

Activities Related to Flood Control

Federal, State, and local efforts toward the reduction of flood damages to the Santa Maria watershed have been carried on for several years. Both structural and vegetative means have been used to provide flood protection, although the main effort to date has been directed toward the maintenance of the vegetative cover. There are a number of agencies--local, county, State, and Federal--working in the interest of flood and erosion control in the Santa Maria watershed. A brief description of their activities follows:

The Department of the Army, Corps of Engineers, completed a flood-control survey of the Santa Maria River in 1939. A new survey, in cooperation with the Bureau of Reclamation, was undertaken after World War II. Findings of this new survey are reported under date of February 10, 1953.

The Department of the Interior, Bureau of Reclamation, has investigated the development of water resources in Santa Barbara County. In June, 1945 a comprehensive basin plan was submitted to the Secretary of the Interior. Investigations were made of 14 dam and reservoir sites. From these investigations, Vaquero and Round Corral reservoir sites on the Cuyama and Sisquoc Rivers, respectively, were selected as the most favorable storage sites.

Since World War II, investigations by the Bureau of Reclamation were resumed in cooperation with the Corps of Engineers and the two agencies have proposed and reported on (House Document No. 217, 83rd Congress, First Session) a comprehensive Santa Maria project to include a reservoir on the Cuyama River at the Vaquero site and a levee system on the Santa Maria River and Bradley Canyon. This project will conserve flood water for replenishment of the ground-water basin in the Santa Maria Valley and protect the valley from floods.

The Bureau of Land Management administers about 60,000 acres of public domain within the drainage. Issuance and supervision of grazing permits and oil leases is the major activity.

The Forest Service, U. S. Department of Agriculture, is active in the watershed. There are 591,895 acres of national forest land within the watershed, representing about 50 percent of the total area. The present area within Los Padres National Forest was placed under administration in 1907. The major activity has been protection from fire. This protection has been gradually improving as facilities become available. Currently, fire protection is being applied to 634,950 acres of land within Los Padres National Forest boundaries at an annual cost of about $89,000. Other work done on national forest land directly affecting flood and sedimentation control includes the seeding of new burns to retard runoff and to hold the soil, road slope stabilization, and reseeding and improvement of range areas.

There are no Soil Conservation Service Districts within the watershed. However, technical assistance is given to the farmers and cooperating State and Federal agencies by the Soil Conservation Service.

The Production and Marketing Administration's agricultural conservation program is applied on approximately 50 percent of the farm and rangeland within the watershed. A partial list of measures which are important in waterflow retardation and erosion control are cover crops, crop residue management, subsoiling, spreader ditches, erosion control dams, range improvements, and establishment of permanent pastures. About 50 percent of the cost of installation is borne by the Federal Government. In 1949 the Production and Marketing Administration made payments totaling about $46,000 to farmers cooperating in the agricultural conservation program.

The Federal-State Cooperative Extension Service promotes, among other activities, an educational program aiding farmers and ranchers in

improving farm and ranch conservation practices directly related to soil erosion and flood control. The cost is apportioned roughly as follows: 50 percent to the State, 25 percent to the Federal Government, and 25 percent to the counties. In 1949 the estimated Federal cost in Santa Maria River watershed was about $150.

The State of California cooperates with the Department of Agriculture under the provisions of the Clarke-McNary Act of 1924. Federal assistance is provided for the protection of privately owned lands having a primary watershed value. The California Division of Forestry protects 79,219 acres of Clarke-McNary watershed land in San Luis Obispo County. About 111,616 acres of Clarke-McNary land in Santa Barbara County are protected for the State by the Santa Barbara County Forestry Department. The annual Federal contribution is about $14,300 through the Clarke-McNary Act.

The State Division of Highways also deals with local flood and erosion control problems in its highway construction and maintenance work.

After the 1909 flood, Santa Barbara County constructed pile and cable jetties along the Santa Maria River to protect vulnerable sections of the south bank between Fugler's Point and the ocean. Periodically, repairs have been made and new jetties built. The county has spent about $400,000 on these works.

The city of Santa Maria constructed a limited capacity ditch in 1941 to divert flood flows from Bradley Canyon to the river east of town. Although inadequate for large flows, it does provide limited protection to the business and residential section of Santa Maria.

The Santa Maria Valley Water Conservation District has issued reports periodically on flood-control and watershed problems in Santa Maria Valley. It also keeps records of well logs and water supply and collaborates with other agencies in plans affecting the area.

Water Economy

The importance of water in the Santa Maria watershed can be appreciated in part by the fact that out of a total of 124,000 acres of cropland 42,000 acres are irrigated. Of this irrigated area, 38,000 acres are located in the Santa Maria and adjoining Sisquoc Valleys. Due to the rotation practices, not all of the 38,000 acres are irrigated each year; part of it is dry-farmed. It has been estimated, however, that approximately 29,000 acres are in irrigated crops throughout or part of each year. The remaining 9,000 acres are planted to dry-land crops such as grain hay, beans, tomatoes, and various others. A large proportion of the 29,000 acres of irrigated land is double cropped so that an estimated total of 35,000 acres of irrigated crops has been harvested from this acreage in the past years. Vegetables constitute about two-thirds of the acreage with approximately 23,000 acres; the remaining acres comprise sugar beets, alfalfa, flower seed, potatoes, and miscellaneous other crops. A more impressive picture is presented when the value of

products raised on irrigated land is compared with that on nonirrigated land. The total f.o.b. value of products produced in 1940 was: 1/

Irrigated crops	$5,500,000
Nonirrigated crops	1,100,000

Carrying this comparison a step further, we find that the total value of the animal industry products represented an estimated value 2/ of about $2,710,000 in 1940. Of this total, approximately $900,000 represents gross return from dairy products, most of which originate in the valley, and their returns should partly be attributed to the irrigated alfalfa pasture and hay lands. In the same way, a portion of the $1,810,000 value of cattle and calves sold should be credited to irrigated lands, especially the amount representing production from about 12,000 head at the Betteravia fattening plant which makes use of sugar beet pulp and tops. It is, therefore, not too much to assume that more than 50 percent of the total agricultural value produced in the Santa Maria watershed is dependent upon an ample supply of irrigation water.

Source and Use of Water.--All of the water used in the Santa Maria Valley is pumped from the underground basins underlying the valley. The critical ground-water area is limited largely to the Santa Maria Valley basin, since the use of water in the Cuyama Valley basin is small, and the supply has not been utilized to the same extent as ground water in the Santa Maria Valley.

The Santa Maria Valley, filled to a depth of three thousand feet with sand, gravel, and clay, functions as an underground reservoir and conduit from which the valley's domestic, agricultural, and industrial water supply is derived. The valley area east of the Southern Pacific railroad (the railroad tracks approximately demarcate the western limit of the artesian area) functions as a reservoir. Here, true water table conditions exist in that the water level fluctuates in direct response to recharge and draft. Ground water in the artesian area is confined beneath impervious clays, and moves laterally under pressure.

Many of the early wells drilled in the western portion of the valley were flowing wells and the artesian area was probably much larger than at present.

1/ Value after being graded, packed, and sold in Santa Barbara County and San Luis Obispo County points. Data for Santa Barbara County, including Oso Flaco district, compiled by the County Agricultural Commissioner's office for San Luis Obispo County estimates.

2/ Based on reported numbers slaughtered or shipped out of the County as reported by the Brand and Hide Inspector.

Concentrated heavy draft in the vicinity of Santa Maria as well as the pumping draft in the western end of the valley has resulted in a reduced artesian area as well as a reduction of the pressure head in wells in the western end of the valley. Pumping costs are probably slightly higher in this area than was the case when the valley was first developed. However, the loss of water from seeped lands, by evaporation from the soil and transpiration by water-loving plants has been reduced. Reduction in the artesian area has probably resulted in some additional underground storage for the conservation of surface runoff now wasting into the ocean.

The ground-water levels have fluctuated greatly since about 1920 with a steady decline through 1936. During the wet years, 1937 through 1945, water levels made about a 50 percent recovery. Figure 1 shows the yearly rainfall at Santa Maria and the fluctuations in water levels at representative wells, as taken from data in the U. S. Geological Survey report on ground-water resources. 3/

The pumping draft on the ground-water basin for irrigation has increased from about 40,000 acre-feet in 1929 to about 57,000 acre-feet in 1944.

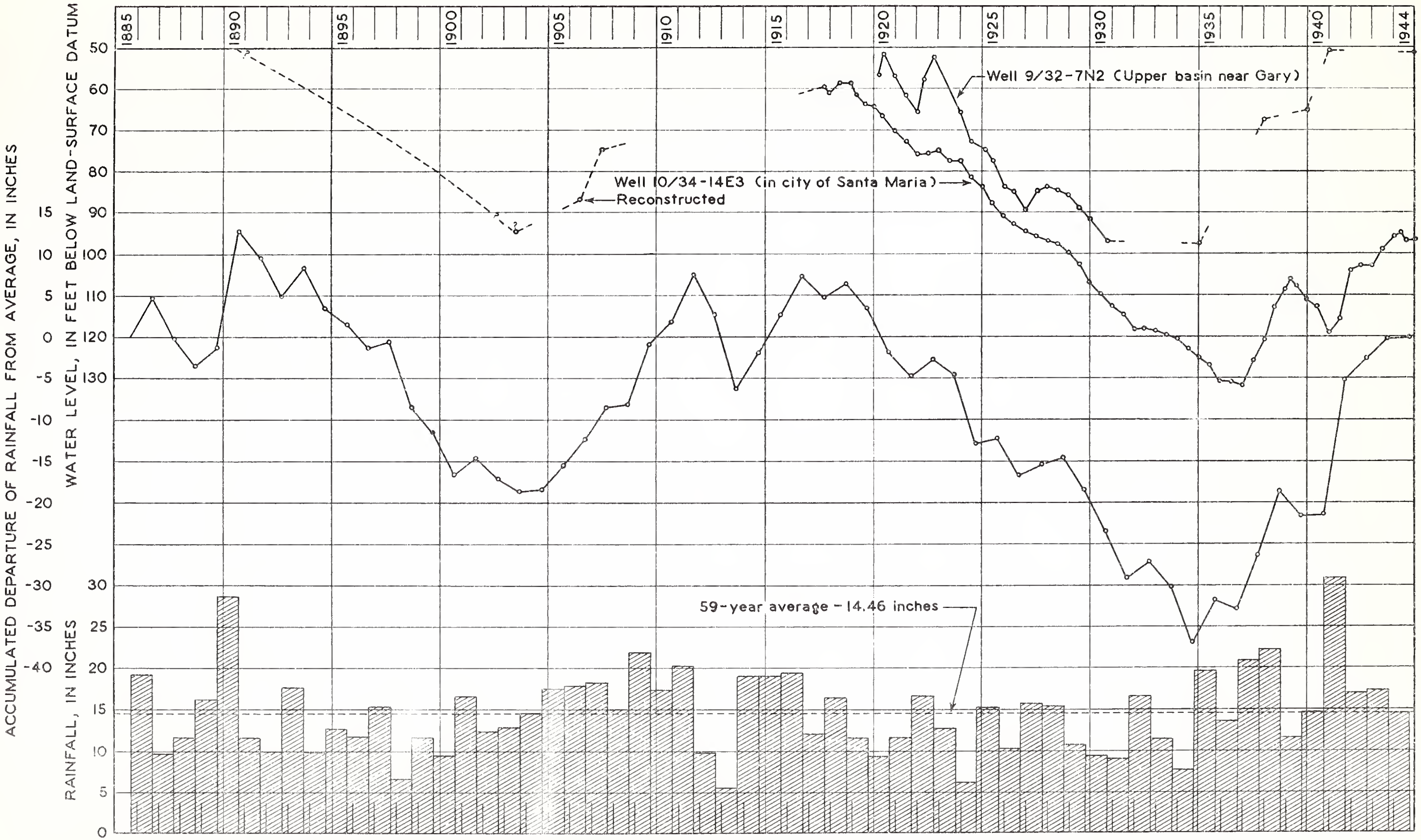
In House Document No. 217 4/ the Bureau of Reclamation points out that based on 1950 conditions, the present total net water requirement is estimated to be about 64,000 acre-feet. This represents an average annual overdraft of 14,000 acre-feet. To alleviate this condition, the Bureau has proposed a reservoir on the Cuyama River for water conservation and flood control. It is estimated that the proposed reservoir will increase the yield by 18,500 acre-feet per year by spreading the retained flood waters in the permeable channel. This substantially increased yield would still be inadequate to meet probable future demands on ground water.

Duty of Water.--Several estimates of the amount of water used per irrigated acre have been made prior to this survey. A tabulation of these estimates follows:

Source	Duty per acre
State Department of Public Works, 1923	1.50
Lippincott Survey, 1930	3.17
Corps of Engineers Survey, 1953	2.00
Bureau of Reclamation, 1953	2.00

3/ U. S. Department of the Interior, Geological Survey. Geology and ground-water resources of the Santa Maria Valley, area, Santa Barbara County, California. Prepared in cooperation with the County of Santa Barbara. March 1947. (Typewritten copy available for examination in offices of Geological Survey, Santa Barbara.)

4/ U. S. Department of the Interior, Bureau of Reclamation. A report on the Santa Maria Project, California. (House Document No. 217, 83rd Congress, First Session.)



GRAPHS SHOWING FLUCTUATIONS OF WATER LEVELS IN WELLS 9/32-7N2 AND 10/34-14E3, 1890-1944; ALSO YEARLY RAINFALL AT SANTA MARIA AND ACCUMULATED DEPARTURE OF RAINFALL FROM AVERAGE FOR THE YEARS ENDING SEPTEMBER 30, 1886-1944

Fig. 1

Data from U.S.G.S. Report on Geology and Ground-water Resources – Santa Maria Valley Area – March 1947

AGR-SCS-PORTLAND, ORE AUG 1953

On the basis of the total amount of water used for agricultural purposes and the estimated acres under irrigation, it is calculated that the duty of water is 2.14 acre-feet per acre or 1.75 per crop. Undoubtedly, this is slightly in excess of the amount of water used per acre for irrigation purposes, since a small amount is used for livestock.

Distribution of Use During the Year.--Eighty percent of the total water for irrigation pumped during the year is applied during the period May to October when soil moisture is deficient and plant growth most active. From the records of agricultural power sales in the Santa Maria Valley for the years 1938, 1939, 1940, the following average percent distribution of irrigation water pumped through the year has been calculated.

Month	Percent of total water pumped
January	1.3
February	.4
March	1.7
April	4.6
May	9.4
June	13.9
July	17.3
August	17.3
September	13.4
October	8.0
November	7.5
December	5.2
Total	100.0

Cost of Irrigation Water.--On the basis of agricultural power sales for pumping, it has been calculated that the power cost of pumping has averaged $3 per acre-foot for the years 1938, 1939, and 1940. To this must be added the cost for depreciation, upkeep, and repair of the pumps which has been estimated at $1.50 per acre-foot. The total cost of water per acre-foot in Santa Maria Valley amounted, therefore, to $4.50 per acre-foot in 1940.

Quality of Water.--The ground and surface waters of the Santa Maria watershed are highly mineralized and hard, typical of waters originating in sedimentary formations of the coast ranges of California. So far, no ill effect resulting from the use of this water for irrigation has been reported, nor is it implied that continued use of this water may ultimately present problems which may bring about less intensive use of the valley lands.

Future Demand for Water.--It has been estimated that the safe yield of the Santa Maria Valley underground basin is 53,000 acre-feet per year. This means that at present a yearly overdraft of about 12,000 acre-feet exists. This overdraft alone should have a retarding effect on further development of irrigation acreage. That the area has reached about its

highest irrigation development under existing economic conditions may be seen from the trend of the estimated area used for irrigation in the Santa Maria Valley as given in the following table:

Table 3.--Estimated irrigated area, Santa Maria Valley

Year	Irrigated area
	Acres
1922	1/ 10,700
1924	2/ 17,341
1930	3/ 26,625
1938	4/ 28,000
1946	5/ 28,571

1/ California State Engineer's Report, 1922.

2/ Chamber of Commerce of Santa Maria.

3/ Lippincott Surveys report on water conservation and flood control of the Santa Maria River, 1930.

4/ Corps of Engineers Survey Report. Flood control on the Santa Maria River and tributaries, 1938.

5/ U. S. Department of Interior, Bureau of Reclamation. Water requirement, water supply, and flood control, Santa Maria basin--comprehensive basin plan, Santa Barbara County Project, California. App. VIII, Mar. 1946.

The main development had evidently come to a close in 1930. Since then, the increase in irrigated acreage was mainly on lands adjacent to the lower Sisquoc River and a slight general broadening of area already under irrigation also occurred. With increased pumping costs due to lowering of the water table, and maintenance of present rotation systems it appears, therefore, very unlikely that the irrigated area would expand materially in the future unless a new supply of water would be provided by the building of storage facilities and spreading grounds.

Increase in urban water requirements may be much greater than previously estimated as the result of the increased activity in the oil industry. The estimated total increase in population for the next 20 years is expected to be about 19,500 for the whole watershed. The total additional need for water in 1970 with an assumed 110-gallon consumption per capita per day then would be about 2,000 acre-feet per year.

Water Rights.--The use of the natural ground-water supply is a common benefit for all overlying lands, and each landowner is entitled to a reasonable use from this supply in common with all other owners of overlying land. Special rights for this use therefore need not be established. Some water use is obtained by diversion from rivers and creeks either by appropriation or riparian rights.

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 3

HYDROLOGIC ANALYSIS OF THE FLOOD PROBLEM

Santa Maria Watershed, California

To accompany report on survey, flood control, Santa Maria Watershed, California.

APPENDIX 3

HYDROLOGIC ANALYSIS OF THE FLOOD PROBLEM

Santa Maria Watershed, California

In the development and evaluation of flood prevention and control activities, information on the size and number of floods to be expected is required. Of equal importance, however, is development of methods for estimating the effects of flood-control measures on flood size. Past floods and past storms furnish the chief clue to both the size and number of future floods that may be expected. To obtain the effects of flood-control measures on future floods, a determination is made of the physical differences in watersheds which will be produced by these measures. Then tests are made of what effects on past floods such physical differences have produced in floods and sedimentation from watersheds.

The major subdivisions of the flood problem in the Santa Maria watershed are (1) the determination of the frequency of peak discharges at damage points in the watershed, and (2) the determination of the sediment delivery at damage and water-use points in the watershed.

Frequency of Peak Discharges

If flood discharges from a watershed had been measured for several hundred years, and if watershed conditions remained static, then the frequency of expected discharges could be readily determined. However, watershed conditions have been changing and are continuing to change. Discharge records are short and have been measured under varying watershed conditions. Therefore, it has been necessary to study flood "causes" to determine how meteorological events combine to produce discharges, and how watershed conditions and changes in watershed conditions affect discharges. The results of these studies permit extension and adjustment of past short-term discharge records before making estimates of discharge frequency, and provide a basis for estimating the changes that flood-control programs will bring about in future flood frequencies.

The particular discharge event whose frequency is needed is often the peak or maximum discharge. If frequency of peak discharges can be determined, average annual damages may be estimated. If the effect of land management or other flood-control measures on discharges can be evaluated, the reduction in damages resulting from a proposed flood-control program may be assessed.

Flood causes may be grouped into two broad categories: the precipitation characteristics and the physical characteristics of the watershed which govern the disposition of the precipitation.

Precipitation Characteristics.--Most of the storms in this region are associated with the extra-tropical cyclones of North Pacific origin.

During the winter months these storms move south over the ocean, being warmed and picking up moisture en route until they are forced landward by the Pacific high pressure zone. As the storms reach land they meet the cold air masses and the mountains which force the moisture-laden air to rise and produce torrential precipitation over much of southern California. Occasionally local thunderstorms which produce high intensities occur both in connection with the general winter storms and independent of them.

Most of the precipitation received in the drainage is in the form of rain. Some snowfall occurs in the high mountains, but snow melt, in this area, is generally considered to have little effect upon the flood flows of the main drainage system.

The distribution of the precipitation throughout both long- and short-term periods influences floods. The short-time intensities of precipitation are critical elements in influencing the magnitude of the peak discharge of the individual flood. At the other extreme, the long-time cycles of precipitation influence seasonal runoff and the frequency of flood events.

In this area the average annual precipitation varies widely. Seasonal rainfall is low at Santa Maria and Ozena, averaging about 14 inches. In the mountain areas at the head of the Sisquoc tributary annual rainfall is as high as 35 inches. For individual years the precipitation has varied from less than one-third to nearly two and one-half times the average annual. Pronounced cycles of wetness and dryness are indicated by the ten-year moving average of the annual wetness, as shown in figure 1. (Figures and tables are located at the end of this appendix.)

The distribution of precipitation by seasons within each year varies widely. During the summertime measurable precipitation is rare since the Pacific high pressure zone moves inland over the southwestern United States effectively deflecting storms from this area. Consequently, about 90 percent of the annual precipitation occurs during the six-month period from November to April.

The amount of high intensity precipitation and the wetness of the watershed are of primary importance in influencing the size of floods. These factors may be characterized respectively by the maximum one-day precipitation and by the 21-day antecedent precipitation to a storm. The distribution of these events for a 53-year period at Santa Maria is given in table 1. These storm precipitation events with their associated watershed wetness have been the primary meteorological causes of past floods in the Santa Maria watershed. For a given meteorological event the size of the flood has been wholly dependent on the characteristics of the watershed upon which the precipitation fell.

<u>Watershed Characteristics</u>.--Watershed characteristics influencing flood problems vary both in space and time.

The geologic types and their associated soils, and the vegetation cover and associated land use are two major watershed characteristics which may influence floods. Geology in the area is highly variable between watersheds whereas vegetation cover is highly variable both between watersheds and in time within a single watershed.

The geological formations are almost wholly sedimentary in origin. With the exception of the Cuyama badland area of Miocene continental deposits, marine sediments of Cretaceous to Quaternary age dominate the mountain areas. Alluvial deposits make up the Cuyama and Santa Maria Valleys. The soils of the mountains vary from fine sandy loams to clays, with rock making up from nearly 1 to 39 percent of the total weight of the soil.

The vegetation which the soils support is characterized by types which are able to withstand, in various ways, recurrent fires and various degrees of soil and atmospheric drought. The types range from annual grasses in the lower areas and some of the level areas of fine-textured soils on the higher ridges, to dense chaparral and conifers on the mountain slopes where water is available, and to near-desert types where precipitation is light. Thus, areal variation in cover density is high. Even within a single rainfall zone, individual tributary watersheds may vary materially in cover density. Field examination indicates that the existing cover types even at full age develop maximum densities ranging from 35 to 60 percent for whole watersheds. Similarly, within individual tributary drainages, greater variation is apparent as the result of fire. In many areas fire has reduced cover density to zero over large areas of individual watersheds. Fire alone has been responsible for modifying the average cover density within single watersheds in recent years from a low of 33 percent to a high of 51 percent density.

Past variations and their effects have been taken into account in evaluating flood-control needs since these variations provide a basis for evaluating the influences of watershed characteristics on runoff.

Runoff.--The discharge records for streams in this basin are relatively short. The U. S. Geological Survey has published in their Water Supply Papers stream flow data for the following streams and periods:

Cuyama River near Santa Maria	-	December 1929 to date
Huasna River near Santa Maria	-	December 1929 to date
Sisquoc River near Sisquoc	-	December 1929 to September 1933 October 1943 to date
Sisquoc River near Gary	-	February 1941 to date
Santa Maria River at Guadalupe	-	January 1941 to date

Flood flows in this basin are characterized by sharp peaks and quick recessions. The maximum recorded peak discharges for the above streams are given in table 2. It is significant that no gaging records were available during the big floods of 1909 and 1914, and that the 1938

flood was only a minor flood in this area. By way of contrast, it has been estimated that the 1909 flood peak was 100,000 c.f.s. and the 1862 flood may have been 200,000 c.f.s. in the Santa Maria River. The need for extending the period of discharge records in this basin before estimating flood frequency is apparent.

Method of Obtaining Peak Discharge Frequencies.--The basic need for determination of peak frequency from a watershed is a long record of discharges for a constant watershed condition. The long record is obtained by: (1) using the short record to determine the relation of peak discharges to precipitation characteristics of the storms causing the discharge, then (2) extending the record to equal the period of the long-term precipitation record by using the relationship found in (1) above.

Estimated discharges for a constant comparable watershed condition are obtained by adjusting the measured discharges for the differences between the watershed cover at the time the discharge was measured and the cover under some standard condition. The magnitude of adjustment needed is obtained by: (1) determining in quantitative terms how differences in watershed conditions in the past affected magnitudes of discharges, then (2) adjusting each discharge to its expected value under some assigned constant comparable watershed condition. The same basis of adjustment is applied to determine how flood-control measures which influence watershed conditions will affect discharges.

Extended Discharge Record.--Floods in this area have been observed to be somewhat independent, both as to occurrence and as to size, from those of watersheds further south, so use of local streamflow and local precipitation records in obtaining flood frequency seems indicated. The Huasna watershed was chosen as the base watershed whose record of discharges was to be extended by correlation with precipitation. This watershed's discharge record was then used in turn to extend the discharge records of other adjacent watersheds by correlation of discharges directly.

The Huasna watershed was suitable as a base watershed in that cover density was nearly maximum and changes had been negligible during the period of discharge records, December 1929 to date. In addition, a complete record of peak discharges for this watershed had been obtained from the original U. S. Geological Survey hydrographs. Thus, some 77 peak discharges were available for analysis instead of the 32 published peak discharges.

Associated with this record of peak discharges and extending back in time some 33 years is a record of daily precipitation at Santa Maria, California, which is near the mouth of the Huasna drainage. This precipitation record was divided into storm events, which are defined as periods of daily precipitation unbroken by days with less than 0.02 inch precipitation. The maximum 1-day precipitation during these storms was taken as an index of their intensity. The amount of precipitation measured during the 21 days antecedent to the maximum 1-day precipitation of the storm was taken as an index of the wetness of the watershed.

The way storm and watershed wetness characteristics combine to produce stream peak discharges was determined by the following steps:

1) For the period when discharge measurements were available, 40 storms were selected from the record to represent all combinations of storm magnitudes--small, medium, and large--occurring on watersheds of dry, moderately wet, and wet conditions.

2) The maximum 1-day and antecedent 21-day precipitation together with the peak discharge associated with the storm were tallied.

3) The relation of peak discharges to the two precipitation variables was determined by multiple regression analysis. A highly significant multiple correlation coefficient and significant partials for the two precipitation variables resulted.

4) The relationship of discharges to the precipitation variables was tested by comparison of observed against computed discharges for the whole record of 77 peak discharges.

5) On the basis of this test equation (a) was obtained, table 3. (Definition of variable given in table 4.)

6) The validity of equation (a), table 3, was tested by comparison of the frequencies obtained by using the actual observed discharges versus the discharges computed from the equation, figure 2. The frequency results are identical, so:

7) For the period of no discharge records, 1897 to 1929, and incomplete discharge records, 1944 to 1949, the missing discharges were computed from equation (a), table 3, using the precipitation records.

8) The observed discharges, plus the computed discharges when observed discharges were not available, made up a 53-year record of discharges from which frequency of (a) maximum yearly and (b) all discharges above a base of 1,000 c.f.s. were determined for Huasna (fig. 3). The plotting formula used was: recurrence interval equals number of years of record plus one divided by the rank order of the discharge event.

The discharge frequencies for other watersheds of the Santa Maria drainage were obtained by correlation of discharges with those of Huasna for comparable watershed conditions. Before correlating discharges adjustments for varying watershed conditions were necessary.

Effects of Watershed Conditions on Discharges.--The only watershed characteristic which has varied radically between watersheds during the short period of discharge measurements has been the cover density as influenced by fire and regrowth following fire. Investigations in other southern California watersheds have shown a highly significant relationship of cover density to peak discharges from watersheds. (See equation (b), table 3.)

It remained to test if such relationships held for the Santa Maria area with its different geology. Such a test was possible using data

from the adjacent Santa Ynez River, a watershed of similar geology and wide variations in cover density with time. Inflow measurements into Gibraltar Reservoir were obtained for the period of 1932 to 1947 when the average cover density on the watershed varied from as little as 27.6 percent in 1934 to as much as 43.7 percent in 1932 and 44.5 in 1947.

Twenty-three measured peak discharges were used with the 1-day precipitation (averaged for 2 gages in the watershed) and the antecedent 21-day precipitation as meteorological controls. Regression analysis gave a value for the cover density function of -0.914 which agrees closely with the -0.852 value from equation (b), table 3. Since the -0.852 value was obtained from much more comprehensive data it was used as the cover effect on discharges throughout this report. The cover function was used both for adjusting discharges to comparable cover conditions so they could be used in frequency determinations and for estimation of effects of measures which influence cover density or could be shown to be relatable to cover density.

<u>"Present" Peak Discharge Frequencies</u>.--Using the extended discharge record of Huasna as a base, the discharge frequencies of other watersheds for "present" watershed conditions were obtained.

This "present" watershed condition is defined as the average cover density that would exist over a period of time under the current level of use and current level of fire protection, grazing, and agricultural land practices. Thus, "present" cover density for a watershed may be different from the actual 1950 cover density inasmuch as the fire occurrence during the preceding several years has not been "average."

Discharge frequencies for this "present" watershed condition were obtained as follows: each of the observed peak discharges of a new watershed with its associated cover condition was converted to its expected value under "present" watershed cover conditions by use of the cover function, equation (b), table 3, and by the ratios of the cover density actually on the watershed at the time the discharge was measured to the cover density expected (on the average) under "present" level of fire protection.

For example, the peak discharge of the Sisquoc River at Sisquoc on February 8, 1932, was 6,240 c.f.s. and the cover density was 43.0 percent. The expected cover density for the watershed under "present" conditions is 47.32 percent. The discharge converted to "present" cover conditions is $6{,}240 \times (47.32/43.0)^{-.852} = 5{,}750$ c.f.s. The 5,750 c.f.s. was used instead of the measured 6,240. In the same manner all discharges were converted to the constant watershed cover condition before being used.

After correcting the discharges of a watershed to a constant comparable condition, the relationship between peak discharges of the watershed and the peak discharges of Huasna for the same storm was obtained. Figure 4 shows such a trend between Huasna River and Sisquoc River at Gary. The trend line was drawn with the aid of a comparison of the ranked events. Using the trend line of figure 4 and the long-term record of discharges

developed for Huasna, the peak discharge record for Sisquoc at Gary was extended and filled in and the frequency of peak discharges obtained. In the same way frequencies were obtained for all subwatersheds of the Santa Maria. These are given in table 5, columns 2 to 6, in such a way that the frequency curves may be reproduced.

Program Effects on Peak Discharges.--The evaluation of the probable effects of various measures proposed for flood damage reduction is the end product of the hydrologic analyses. The frequencies of peak discharges provide a hydrologic base for estimating expected damage under "present" condition. After effects of proposed measures on peak discharges are determined, the effects on flood damages may be estimated. There are three general categories of measures requiring evaluation: fire control, range improvements, and cropland improvements.

Effect of Fire Control.--The intensified fire-control measures have as their objective the maintenance of an optimum wildland cover density expressed as a reduction in the average annual acreage of area burned. The physical effect of reduction in burn percent is a smaller area of low density young cover, and therefore greater average cover density on the watershed. The relation of cover density to cover age for various geological-soil groups and various species was developed by J. S. Horton and summarized in table 6 so that the growth curves may be reproduced. The average cover density on a watershed is, then, the area weighted average of the cover densities read from the appropriate growth curves for the particular age of the cover. The average annual burn is converted to its equivalent cover density by assuming that age distribution is the same as if the annual burn occurred each year; thus, if the average burn were 1 percent there would be 1 percent of the area in each age class from 0 to 99 years old. The average cover density would be read from the appropriate growth curves or in practice an average recovery curve was drawn for a watershed and that curve used to obtain average cover density for a particular burn percent. The effect of a change in burn percent resulting from intensified fire control was converted to change in average cover density on the watershed.

The effect of the change in cover on peak discharges was obtained by substitution in equation (b), table 3. For example, the present expected annual burn in the Sisquoc watershed was 1.28 percent and the fire-control measures were designed to reduce this to 0.2 percent. The average cover densities under the two conditions would be 46.52 and 51.5 percent. The equation showed peak discharges varied as the -0.852 power of the cover densities; so $(51.5/46.52)^{-.852}$ gives 0.917 as the factor by which peak discharges would be reduced by the proposed fire-control measures from present conditions, that is an equivalent of 8.3 percent reduction. Thus, the evaluation of these measures could be made directly by application of effects found by analyzing fire results in adjacent watersheds.

Effect of Range and Cropland Improvements on Peak Discharges.--For the estimation of the effect of improved grazing management on discharges it was necessary to make indirect estimation by using infiltration indices.

$\left(\frac{51.5}{46.52}\right)^{-.852} = 1.107^{-.852} = \frac{1}{1.107^{.852}}$

The influence of grazing intensity on infiltration capacity under controlled experimental conditions is indicated by the following results at the San Joaquin Experimental Range:

Number of plots	Experimental treatment	Number of tests	Infiltration capacity, soil at field capacity	Significance
			Inches per hour	
3	Ungrazed 5 years	9	8.0	
3	Ungrazed 3 years, moderately grazed 2 years	9	5.8	Significant
3	Ungrazed 3 years, heavily grazed 2 years	9	3.4	Highly significant

These infiltration determinations are indicative of the changes in the hydrologic characteristics of the soil under grazing conditions. Similar indices were obtained for grazing conditions in the Santa Maria area.

Three intensities of grazing were recognized--heavy, moderate, and light. Infiltration measurements were made on the three types by use of the "FA" infiltrometer. Seventeen determinations were taken on heavily grazed areas, 22 on moderately grazed, 12 on the lightly grazed, and 42 on various degrees and types of agricultural lands. Similar determinations were made in chaparral cover types of various ages and cover densities. For the latter it will be recalled that direct determination of the effects of cover density changes on discharges had been made by regression analyses discussed previously. Conversion of the grazing intensity classes to their hydrologic equivalents in terms of cover densities was made by using the infiltration measurements as indices. The following steps were taken:

1) The infiltration capacities as determined by the infiltrometer were multiplied by a factor of 0.3. 1/ These are called the adjusted

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1/ From "A Method of Hydrologic Analysis in Watershed Management," P. B. Rowe. Trans. Amer. Geophys. Union, Pt. II, 1944, pp. 632-49. It was found, after allowance for soil and channel storage had been made, that if the infiltration measurements were multiplied by a factor of 0.3, approximate reproduction of the stream flow hydrograph resulted. It should be noted that the same relative effects of grazing intensities and agricultural uses are obtained by using either the unadjusted or the adjusted infiltration indices, but the adjusted values give positive values of rainfall excess for the storms which are known to produce surface runoff and yield equivalent cover densities which are close to the observed for the various uses, so the adjusted indices will be used.

infiltration indices. Unadjusted and adjusted infiltration for various land-use categories involved in the program for flood and sediment reduction in the Santa Maria are given below:

Cover type	Degree of use or cover age	FA infiltration capacities 70-90 minutes after start of application	Adjusted infiltration index
		Inches per hour	Inches per hr.
Grassland	Heavy	0.62	0.19
	Moderate	1.88	.57
	Light	3.12	.94
Cultivated			
Clean tilled		0.30	.09
Treated		1.14	.34
Chaparral	0-3 years old	1.21	.36
	4-7 years old	3.16	.95
	8-15 years old	4.85	1.46
	16+ years old	6.52	1.96

2) Maximum rainfall rates for several frequencies of storms were then estimated. These were developed from Corps of Engineers design storm data, and are given below:

Cover type	Maximum hourly rainfall rates for storms of various recurrence intervals		
	100-year	50-year	25-year
	In./hr.	In./hr.	In./hr.
Grassland	1.37	1.18	1.00
Cultivated	1.37	1.18	1.00
Chaparral	1.75	1.48	1.25

3) Rainfall excesses over infiltration, for the cover conditions and ages for the various sizes of storms, were obtained by subtracting the adjusted infiltration indices from the rainfall rates:

Cover type	Cover density	Rainfall excess for storms of recurrence intervals 100-year	50-year	25-year
	Percent	Inches	Inches	Inches
Grassland				
Heavy use	1/6	1.18	0.99	0.81
Moderate use	1/13	0.80	0.61	0.43
Light use	1/42	0.43	0.24	0.06
Cultivated				
Clean tilled	1/4.7	1.28	1.09	0.91
Treated	1/9.2	1.03	0.84	0.66
Chaparral				
0-3 years old	4	1.39	1.12	0.89
4-7 years old	14	0.80	0.53	0.30
8-15 years old	54	0.29	0.02	.00
16+ years old	65	.00	.00	.00

1/ Estimated equivalent effective cover density based on comparative rainfall excesses with chaparral cover.

If we assume that rainfall excess is an index of relative runoff-producing potential, we can obtain an estimate in terms of cover density of the effectiveness of light, moderate, and heavy grazing and of treatment of agricultural land on runoff. For example, the rainfall excesses under moderate grazing for the 100-, 50-, and 25-year storms were 0.80, 0.61, and 0.43 inches, respectively; reference to the standard, the chaparral, shows that these excesses are obtained under about a 13 percent cover density. Hence moderate grazing use was assigned 13 percent as equivalent cover density effectiveness.

The equivalent cover densities for light, moderate, and heavy grazing and for two agricultural land classes were obtained by similar comparisons of rainfall excesses and are listed in column 1 of the above table.

Expressing this effectiveness in terms of equivalent chaparral cover density will permit estimation of effects on peak discharges of changing a given area from one degree of use to another. The estimate of the effect on discharges is obtained by substituting the equivalent cover change in equation (b), table 3.

The resulting changes in peak discharges for the program outlined in Appendix 5 are shown in columns 7 to 11, table 5. The factors given were obtained by substituting equivalent cover densities in the equation as illustrated on page 7 of this appendix. The flood flows expected under "present" watershed conditions were multiplied by these factors to give flood frequencies expected in the future without and with the program.

Relation of Sediment Production to Sediment-Producing Events, Geology, and Watershed Conditions

An important source of the damages produced in watersheds is the sediment produced by the floods. If proposed reservoirs are built, the rate at which sediment will use up their capacity must be known. In addition, the rate that sediment deposits are restricting channel capacities must be estimated. Thus, determination of the expected sediment production rates from subwatersheds of the Santa Maria basin is needed for flood-control evaluation. The average annual sedimentation may be said to depend on (1) the frequency of events causing sediment movement--peak discharges may be used as the defined event--and (2) on the relation of the amount of sediment produced to the size of these events for various watershed characteristics and conditions. Frequencies of discharges expected from the watersheds of the Santa Maria have been developed previously, table 5.

Relation of Sediment Production to Discharges.--Some findings of the relation of sediment production to maximum yearly peak discharges were reported for other watersheds of southern California (equation (c), table 3). Since the geology of that area was different from the Santa Maria, it was desirable to make tests to see if a different relationship to discharge held here. Eight periodic measurements of sediment production in the Gibraltar reservoir in the watershed adjacent to the Santa Maria provided the basis for such a test, table 7. Regression analysis of the sediment catches against the discharge function being tested ($q^{.866}$)--from equation (c), table 3--and the average cover density during each period, table 7, gave equation (d), table 3. The factor 0.945 for the discharge function is considered to be close enough to 1.00 to indicate that no modification of that function need be made for the Santa Ynez watershed.

Thus it was shown that the function relating sediment production to peak discharges found in other southern California watersheds also held in the Santa Ynez watershed. The Santa Maria subdrainages are sufficiently similar to the Santa Ynez so that it may be postulated that the Santa Maria drainage has the same sediment-peak discharge function common to the areas tested.

Relation of Sediment Production to Watershed Cover.--As with the discharge function, the relationship of sediment production to cover density found in some other southern California watersheds (equation (e), table 3) was checked. The catches in four reservoirs--the Gibraltar, the Juncal, the Mono, and the Caliente--all in the adjacent Santa Ynez drainage, were used. Although peak discharges were available only for Gibraltar, by using the precipitation effectiveness ($1.619 \log P'_1 + 0.410 \log aP'_{21}$) from equation (e), table 3, as an index of the sediment-producing potential of the storms of a period, it was possible to use all 13 of the sediment catches, table 7. Regression analysis of these average annual sediment catches against the average precipitation effectiveness and the average cover density during the periods gave equation

(f), table 3, as the result. The factor for precipitation effectiveness is seen to be 0.941 which is close to 1.00, and the factor for cover density was -1.980, which is practically identical with the -1.974 obtained in the more extensive southern California studies and given by equation (e), table 3.

Thus it was shown that not only the function relating sediment production to discharges but also the function relating sediment production to cover which was found in other southern California watersheds held in the Santa Ynez watershed. The Santa Maria subdrainages are sufficiently similar to the Santa Ynez so that it may be postulated that the Santa Maria drainage has the same sediment-cover function common to the areas tested.

Although the general functions relating sediment production to flood peaks and cover density, obtained from more numerous data in southern California, were found to be usable in Santa Maria watersheds, marked differences in the constants in the equation, that is, in sediment production per unit discharge from watershed to watershed, were found. These differences were found to be related to the geologic-soil characteristics of the watersheds.

<u>Relation of Sediment Production to Soil-Geologic Types of Watersheds.</u>-- The actual measured sedimentation in the Gibraltar watershed was used as a base for (1) adjusting the constant in equation (c), table 3, for soil-geologic differences and (2) as the reference from which estimates of expected sediment production from Santa Maria watersheds could be made by application of discharges and cover and adjustment for differences in soil erodibility.

First an equation for sedimentation in Gibraltar was obtained by adjusting equation (c), table 3, on the basis of the ratio of the computed sedimentation for the 27-year period to the actual sedimentation. This gave an adjustment factor of 0.445 and when 2.15 is inserted for the channel area equation (g), table 3, results.

Sedimentation expected from subwatersheds of the Santa Maria varied from those of the Gibraltar due to variation in the frequency of peak discharges, in the cover density, and in the inherent differences in the erodibility of the soils of the areas. Equation (g), table 3, gives the relation of sedimentation to each of the factors, except erodibility. To obtain indices of "erodibility" it was found desirable to take soil samples from the major soil-geologic types, determine some of their physical characteristics in the laboratory, and test how these physical characteristics were related to measured sediment production from watersheds.

Several soil scientists have proposed physical characteristics of soils which are related to soil erodibility. The work of Middleton was a notable early attempt. He determined the physical characteristics of some soils and found that those soils with high values of these characteristics (dispersion ratios greater than 15, erosion ratios greater

than 10) were generally classed as erodible; whereas those with low values were generally the nonerodible. These results suggested that indices of soil erodibility might be obtained from relatively simple soil measurements. Therefore, soil samples were collected from the major soil-geologic types in the Santa Maria and adjacent Santa Ynez drainages.

Soil Sampling.--Soil samples of the 0- to 6-inch depth of soil were taken so as to have one or more samples from each major soil-geologic type in the watershed. The samples were all collected on slopes of about 35 percent and under cover conditions which were judged to be average for the vegetation type. Each sample was subjected to laboratory physical analyses, including mechanical analysis from rock and gravel to clay down to 0.15 microns, colloids by absorption, suspended silt plus clay after shaking for 0, 2, 20, 180, and 1,440 minutes, and the moisture equivalent. From the results of these determinations, several erosion ratios were calculated and tested.

Relation of Physical Soil Characteristics to Sediment Production.--Before the soil physical characteristics could be used to estimate sediment production from watersheds, tests were made to determine their relation to sediment production and how they were quantitatively related.

Some measured sediment productions were available for the watersheds in which the soil samples were taken. These were of two kinds: stream suspended load measurements and sediment deposition in reservoirs. The average sediment content of the streamflow for 14 watersheds varying in areas from 10.6 to 1,763 square miles had been determined, table 8. In addition, the sediment deposition in 4 reservoirs, with watershed areas of from 16 to 219 square miles had been measured. The last included 13 measurements of sediment deposition, and are given in table 7. Thus, 14 watersheds with their sediment production measured in terms of suspended sediment and 4 watersheds with their sediment production measured in terms of sediment deposited in their reservoirs furnished the bases for testing the relation of soil physical characteristics to sediment production.

Many physical soil characteristics were tried as parameters. Combinations of suspended silt plus clay, ultimate silt plus clay, micro clay, colloids, gravel, and moisture equivalent were studied. The ratios which were proposed by Middleton to express erodibility proved to be about as good as any new ones tested. The basic physical determinations and the most promising erosion ratios for the various major soil-geologic types are given in table 9. The areas of the various geologic types in the watersheds used in the analyses (and in the final application of the results) are given in table 10 together with the erosion ratios for the watersheds.

For the areas above sediment measurement points, the average values of the "erosion ratios" were determined by weighting the mean ratio for the soil-geologic type by the areal extents of the geologic types in the watershed.

Suspended Sediment.--The relation of the amount of suspended sediment to the various erosion ratios of the soils in the watershed was determined by regression analyses. Equation (i), table 3, gives the least-square fit of the data and the correlation coefficient. Both the cover density, C, and the suspension to colloid, S/C, ratio were highly significant. The relation of calculated to actual sediment is shown in figure 5 for the ratio of suspended silt plus clay/colloids, S/C. Any of the three erosion ratios listed would give a good enough index of relative erodibility, but the S/C ratio was selected because it seemed theoretically most sound and had the least standard error.

Sediment Deposition.--The relation of the amount of sediment deposition in reservoirs to the erosion ratios was determined by regression analysis of the 13 catches given in table 7, and the erosion ratios from table 10. Equation (j), table 3, gives the equation relating sediment deposition to the ratio suspended silt plus clay/colloids when the meteorological and cover effects had been eliminated.

It will be noticed that the function for the S/C erodibility variable was nearly identical in the suspended sediment and the sediment deposition equations: 0.0146 and 0.0183. This, in a way constitutes a check of the results. The S/C function for deposition has been used to calculate the erodibility of the soils of the various watersheds and the results are given in column 2 of table 11. From these, relative erodibility of the watersheds expressed in percent (Santa Ynez River at Gibraltar taken as 100) was calculated and is given in column 3 of table 11. The relative erodibility has been incorporated into equation (g), table 3, which was developed for the Gibraltar watershed, to give equation (h) which applied to each of the Santa Maria subdrainages when relative erodibility is taken into account.

Average Annual Sedimentation.--The peak discharge frequencies developed give expected number and sizes of future floods (table 5, fig. 3) and equation (h), table 3, gives the amount of annual sedimentation for any size flood--for some particular watershed condition and relative erodibility. Average annual sedimentation is, then, merely the sum of the annual erosions obtained by substituting the discharges from the frequency curve in the equation with proper values of cover density and erodibility. Sedimentation estimates for "present" watershed conditions for watersheds of the Santa Maria basin are given in column 4, table 11.

These values were checked in two ways: (1) by comparing the sedimentation calculated in this way with that of average suspended sediment (table 8) times the average annual total stream flow and (2) by comparison of totals computed for the parts of the Santa Maria (Cuyama plus Huasna plus Sisquoc) with the computed values for the Santa Maria watershed as a whole. After adjustment for differences in watershed cover these checks gave sufficiently close agreement with the original calculated values to indicate the results are probably valid.

Effect of Program on Expected Sedimentation.--The effects of program on expected sedimentation depend on the effects of the several measures on

discharges and then their additional effect on the amount of sediment per unit discharge. In the section "Effects of Program on Discharge" the effects have been shown to be expressible in terms of their effects on average cover density in the case of fire control and in terms of equivalent cover density in the case of the range and cropland improvements. The gross effect of changing cover density on sedimentation is given by the cover function in equation (e), table 3. The change in sedimentation with change in cover density is seen to vary as the -1.974 power of the cover densities. This change is verified by independent studies of the cover effects obtained from other data (equations (f), (j), and (k), table 3). Using the changes in cover associated with the fire, range, and cropland measures the estimated sediment production is obtained. For example, the Sisquoc River at Gary has an expected average annual sedimentation of 1,860 cubic yards per square mile under "present" fire protection level with an associated average cover density of 46.52 percent. Under intensified fire protection the average cover age would increase and the cover density would be 51.5 percent. Reduction of sedimentation by fire control is then

$$1{,}860\left[1-(51.5/46.52)^{-1.974}\right]$$

or an average of 339 cubic yards per square mile per year for the whole 442-square-mile watershed, or an 18 percent reduction. The future watershed conditions with and without the programs outlined in Appendix 5 were converted to their equivalent change in cover density (using the tabulation on page 10 of this appendix). The changes in sedimentation expected with these changes in cover density were calculated. These are given in columns 5 to 10, table 11.

An illustration of how fire increases sediment production is presented in the annual reports of the Santa Clara Water Conservation District, 1931-32 to 1934-35. The data include some for the Sespe watershed which is adjacent to the Santa Maria and of the same general cover and geology. The District took stream sediment samples the year before and for several years following the 1932 fire which burned 76 percent of the Sespe watershed. The difference in sediment production is strikingly shown when sediment content of the water is plotted against stream flow, figure 6. The runoff for the first 2 years after the fire had an average of 6 times as much sediment as the year before the fire. The stream flow from the first storm after the fire had very high concentrations of ash and debris--2,400 p.p.m. of soluble matter and 400,000 p.p.m. of suspended sediment.

Program Effects on Expected Sedimentation of Proposed Vaquero Reservoir.--Vaquero Reservoir, to be created by a dam 184 feet high on the lower Cuyama River, is an integral part of the joint plan for flood control and water conservation of the Bureau of Reclamation and Corps of Engineers. The reservoir will have an initial capacity of 214,000 acre-feet, 89,000 of which is to be reserved for flood control. The remaining 125,000 acre-feet is the initial conservation pool which is to be used to store water for later release. The water stored in the conservation pool will be released at a rate which will permit the water to percolate through the river-bed sands downward to the Santa Maria ground-water basin. Pumpage from this ground-water basin is the sole source of irrigation water for the agricultural lands of the Santa Maria Valley. Present average overdraft from the ground-water basin has been estimated as 14,000 acre-feet per year 1/. Additional supply to this basin of water which would otherwise be lost to the sea is to be effected by Vaquero Reservoir.

The effectiveness of Vaquero Reservoir in saving water for percolation to ground water is dependent on the capacity of the conservation pool. Initially this pool will have a capacity of 125,000 acre-feet. However, the capacity of this pool is subject to depletion by sedimentation. In turn, the rate of sedimentation and therefore the rate of loss of conservation pool capacity is subject to modification by land use and the cover changes in the watershed above the reservoir.

Treatment of the watershed lands above Vaquero Reservoir so as to reduce sediment production is a part of the U. S. Department of Agriculture's proposed program for the Santa Maria Basin. The effect of the USDA programs on future sedimentation of Vaquero Reservoir and the resultant influence on water percolated to the Santa Maria ground-water basin has been estimated. In order to facilitate coordination of the program of the U. S. Dept. of Agriculture with those of the Bureau of Reclamation and the Corps of Engineers, physical facts, results of studies, and assumptions used by the last two agencies in preparation of their programs have been retained intact in evaluating the U. S. Department of Agriculture's program.

Present and Future Rates of Sedimentation.--The rate of sedimentation of Vaquero Reservoir under present watershed conditions has been jointly determined by the Bureau of Reclamation and the U. S. Department of Agriculture, by averaging very similar separate determinations 2/. The method used by the U. S. Department of Agriculture in

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1/ Bureau of Reclamation, Santa Maria Project, Southern Pacific Basin, California, H. D. 217, 83rd Congress, 1st Session, page 54.

2/ Bureau of Reclamation, Santa Maria Project, Southern Pacific Basin, California, H. D. 217, 83rd Congress, 1st Session, page 67.

determining sedimentation is outlined in detail on pages 11-14 of this appendix, with the average annual rates being given in table 11. The rate of sedimentation of Vaquero under present watershed conditions has been taken as 900 acre-feet per year. This rate will vary under future expected watershed conditions, both with and without the U. S. Department of Agriculture program.

The effect of the USDA program on sedimentation and the probable future sedimentation rate with and without the program has been estimated, pages 14 and 15. The changes in the present sedimentation rate with and without the program are given in table 11. Thus, the future sedimentation rate with the watershed protection program is estimated at 655 acre-feet per year, and the future sedimentation rate without the program is 1,446 acre-feet per year. The programs and projected cover conditions which form the basis of the estimates are given in Appendix 5.

Effects of Sedimentation on Yield to Ground Water.--The effects of sedimentation on the capacity of the conservation pool are reflected directly in the amount of available water to be percolated to the ground-water basin. The relation of conservation pool capacity in Vaquero to the resultant percolation to ground water developed by the Bureau of Reclamation 1/ has been used and is shown graphically in figure 7.

Applying this relationship together with the sedimentation rates given previously, estimates were made of the conservation pool capacity and the percolation to ground water during a 200-year period assumed to begin in 1957 for three watershed conditions: the present watershed condition, the future watershed condition without the USDA program, and the future watershed condition with the USDA program, table 14. The relation of percolation to ground water to the age of the reservoir for the three watershed conditions is shown in figure 8. The middle trend line of figure 8 closely agrees with that developed by the Bureau of Reclamation 1/. The other two trends show loss in available ground water with age of the reservoir under probably future watershed conditions with and without the USDA program. Thus, it may be seen that the watershed protection program will more than double the life of Vaquero Reservoir.

1/ Bureau of Reclamation, Santa Maria Project, Southern Pacific Basin, California. H. D. 217, 83rd Congress, 1st Session, Plate 6.

<u>Channel Sedimentation with the Santa Maria Project Installed 1/</u>. An evaluation has been made of the effects of the U. S. Department of Agriculture's proposed watershed protection program in reducing channel sedimentation, after the completion of the Santa Maria Project--Vaquero Reservoir and the main channel improvements.

The evaluation is based on the suspended sediment component of sediment, bed-load being unevaluated. Sediment deposition in the channel was taken as the difference between suspended sediment inflow and outflow--inflow from the Sisquoc River and Bradley Canyon, and of the Santa Maria River at Guadalupe had been sampled in connection with an early survey of this basin by the U. S. Department of Agriculture. The results of this sampling, together with stream discharge frequencies, furnish an estimate of sediment inflow and outflow. These results are summarized in Table 13, together with the resultant sediment discharge.

1/ Extracted from preliminary report "Evaluation of Effect of USDA Program on Suspended Sediment Inflow and Outflow, Santa Maria Channel," by H. W. Anderson, August 25, 1953.

Sediment Inflow: Average annual sediment inflow to the channel from the Sisquoc and Bradley Canyon, tables 13A and 13B, total 412 acre-feet per year for a period with discharges similar to those of 1930 to 1948 and for present watershed conditions.

For future conditions without and with the USDA program, the sediment inflow was taken as proportional to the estimated sedimentation shown in table 11, weighting the Sisquoc and Bradley rates by their respective watershed areas. The resulting average suspended sediment inflow without the program would be 616 acre-feet per year, and the sediment inflow with the program would be reduced to 328 acre-feet per year.

Sediment Outflow: Sediment outflow is limited by the amount of water which will be permitted to escape to the sea. Before installation of Vaquero the average annual outflow to the sea was 31,200 acre-feet. With the Santa Maria Project installed 18,500 of this will be saved by percolation to the ground water and 1,300 acre-feet will be lost as evaporation from Vaquero Reservoir 1/, leaving an average outflow of 11,400 acre-feet. This outflow, distributed into daily flow-duration, together with associated sediment concentration and resultant sediment discharge, is shown in table 13C. Thus, sediment outflow from the Santa Maria Channel with the Santa Maria Project installed is estimated as 248 acre-feet per year for periods similar to the 1930-48 period, and for present watershed conditions.

Under future projected watershed conditions, if sediment outflow is assumed proportional to sediment production, average sediment outflow without the U. S. Department of Agriculture program would be 248 x (616/412) = 371 acre-feet per year, and sediment outflow with the program would be 248 x (328/412) = 197 acre-feet per year.

Sedimentation of Santa Maria Channel During Non-Flood Periods: The contribution to sedimentation of the Santa Maria Channel by suspended sediment inflow from the Sisquoc and Bradley Canyon areas may be taken as the difference between estimated inflow and outflow of sediment. These are summarized below for three watershed conditions and resultant sediment production rates, together with the equivalent average depth of deposition in the 2,200 acres of channel area:

1/ Santa Maria Project, Southern Pacific Basin, California, Bureau of Reclamation, H. D. 217, 83rd Congress, 1st Session.

Watershed condition	Suspended sediment inflow AF/yr.	Suspended sediment outflow AF/yr.	Difference AF/yr.	Average equivalent depth of deposition* Ft/yr.
Present	412	248	164	0.075
Future without USDA program	616	371	245	.111
Future with USDA program	328	197	131	0.060

*In Santa Maria Channel

It has been estimated that flushing floods occur on the average 50 years apart. Then the first flushing flood will occur on the average 25 years after establishment of the improvements in the Santa Maria Channel. Average sedimentation depth in the Santa Maria Channel contributed by the Sisquoc and Bradley Canyon is expected to be, therefore, under present watershed conditions, 0.075 times 25 or 1.9 feet; under future watershed conditions without the U. S. Department of Agriculture program, 0.111 times 25 or 2.7 feet; and under future watershed conditions with the program 0.060 times 25 or 1.5 feet. For longer periods of non-flushing flows proportionally greater depths of deposition may be expected.

The analyses indicate that during periods between major flushing flows deposition in the improved channel will occur. Deposition is likely to be sufficient to require removal of sediment to maintain channel capacity. The U. S. Department of Agriculture program by reducing the amount of sediment production will reduce the amount of sediment needed to be removed.

Another important source of damage from channel sedimentation is the sealing of percolation beds, both natural channel beds and artificial spreading grounds. The effect of the U. S. Department of Agriculture program on this source of damage has not been evaluated. It is to be expected that reduction in sediment production by the program will tend to reduce this damage.

Design Sedimentation.--For purposes of designing reservoirs and evaluating their effectiveness and economic feasibility, it is necessary to know the storage capacity which must be allowed for sediment over a period of time. The average annual sediment production has been determined for the Santa Maria streams by use of the equations developed and expected flood frequencies under certain assigned values of watershed cover densities.

In designing spreading grounds, channels, and debris reservoirs it is necessary to know the storage capacity which must be allowed for sediment for a single large storm, assuming some coincident poor watershed condition. An approximation of this allowable storage capacity may be obtained from the results of this study.

The storm which produces the flood of 100-year recurrence interval may be arbitrarily chosen. The area of brush cover may serve as an expression of fire hazard, and a possible poor watershed condition might well be such as would result if an area equal to one-fourth of the brush area burned and the storm occurred the first year after such a burn. By using the 200-year intercept of the discharge frequency curve, figure 3, or by extending values from the discharges given in table 5, as the mean size of this flood and using equation (h) of table 3 and the expected cover density and erodibility, we obtain the estimates of sedimentation listed in column 11, table 11, which have been termed "design sedimentation."

Conclusions

The studies made to develop a hydrologic base for evaluation of the watershed treatment program indicated the following:

1. The observed discharges in this area, where discharge records are short and major fires cause wide variation in forest cover, are not a satisfactory base for determining frequency. Furthermore, flood frequencies were apparently different from those for areas further south. Therefore, adjustment of the observed discharges to a uniform forest cover condition and extension of the record on the basis of the long-term local precipitation record were made to provide a base for flood frequency estimates.

2. Sedimentation in an individual reservoir likewise is not often a good index of the long-time average to be expected. If the record of sedimentation is short, floods during this period may not be representative. Even if the record of sedimentation is fairly long, the fire history may not be representative or the coincidence of fires and storms may be exceptional. Thus the actual sedimentation of a reservoir in the 219-square-mile Gibraltar watershed during a 27-year period is 1.3 acre-feet per square mile per year, whereas the expected amount under the present fire-protection level, based on frequency of expected discharges, is only 0.9 acre-feet per square mile per year.

3. Studies of the physical characteristics of the soils of the Santa Maria basin indicate that 75 percent of the soils are of high erodibility, 8 percent of moderate erodibility, and 17 percent were not sampled as to erodibility. Sediment production

was highly variable from watershed to watershed depending on the geology of the area. Average suspended sediment of the runoff water varied from as little as 3,900 p.p.m. to as much as 192,300 p.p.m. Both suspended sediment and sediment deposition were related to some physical characteristics of the various soil-geologic types. These relations provided a basis for improving the estimates of expected average annual sediment production.

Basing estimates of average sedimentation on the long-time extended discharge record and adjusting for erodibility and expected average cover conditions provided estimates which made allowance for widely varying erodibility and were independent of chance conditions of fire history.

4. Past discharges and sediment production in this basin have been moderately high. The studies indicated that improved fire protection, grazing practices, and cropland treatment can bring about significant reductions in peak discharges and sediment production.

   It should be pointed out that the cover effects here measured, both for sedimentation and peak discharges, apply only to the present general level of watershed conditions. If during some future interval of time, the watershed receives improved treatment and protection for a long period, then soil building may occur and the maximum cover density may have an effect even greater than found here. If, on the other hand, further misuse continues, the vegetation which occupies the area may be expected to become less and less dense. Under such conditions of decreased cover effectiveness, cover changes will be necessarily smaller, and a sustained higher level of peak discharges and sedimentation may be expected to result.

5. The U. S. Department of Agriculture watershed treatment program will play an important role in maintaining the effectiveness of Vaquero Reservoir. Without the program watershed cover conditions will deteriorate, sediment rates will increase, and the total life of the water conservation pool will be only about 90 years; with the program and the subsequent reduction in sediment production, the expected life is in excess of 200 years. Thus the program will more than double the life of the reservoir, with attendant benefits to water supply resulting.

6. The results of the effects of the USDA program on sedimentation of the Santa Maria channel, after Vaquero Reservoir is in operation and the Corps' channel improvements are installed, are considered adequate for estimating minimum benefits expected from the land-use program. The estimates should not be taken as the Department's estimate of the true physical situation with respect to the sediment problem. In every case where alternative assumptions were

possible, the minimizing assumption was chosen: (1) Suspended sediment was used alone, although bed load would also contribute to channel sedimentation; (2) sediment contribution of the Sisquoc and Bradley areas alone were considered, although some contribution to sediment inflow from the Cuyama may be expected; (3) sediment outflow under future conditions without the program was assumed to be increased proportional to sediment inflow, although sediment outflow might reasonably be increased much less and therefore sedimentation would be much greater; and (4) sediment production from the Sisquoc has been taken as if the watershed were in the average expected "present" condition, although the watershed is in better than average "present" condition, so future increases in sediment production without the land-use program will be greater than estimated.

7. The study complies with the six criteria upon which a study in applied hydrology may be evaluated: In determining the basic relations (1) the data are representative in time--this was considered to be fairly well met because the data used covered more than 15 years of discharges and 53 years of meteorological records; (2) the data used are representative in space--relations used were based on extensive studies in nearby areas of southern California and tested for their applicability to this area; (3) the effects measured are representative of actual effects--in this case they were the actual effects of meteorological and watershed variables on discharges and sediment production from whole watersheds in the case of fire effects and the use of infiltration indices in the cases of the grazing and cropland treatment effects; (4) the effects measured are related to the desired end products, the damages produced by floods; (5) a suitable measuring device was employed, multiple regression analysis, and standard engineering procedures; and (6) in the application of the results, tests were made for the individual cases whenever possible. Despite attempts at obtaining adequate statistical bases for the findings and devising of checks on the findings, the possibility of error cannot be overlooked. In order that the assumptions, reasonings, and evaluations may be checked, full data have been given insofar as practicable.

Table 1.--Maximum daily precipitation of storms and associated 21-day antecedent precipitation for Santa Maria, California, 53-year period, January 9, 1897, to December 19, 1949

Maximum daily precipitation during storm	Number of storms with 21-day antecedent precipitation (in inches) of:							
	0-.99	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-5.99	6.00-6.99	7.00+
Inches	No.	No.	No.	No.	No.	No.	No.	No.
0.01 - 0.24	460	80	70	70	20		10	
0.25 - 0.49	160	50	20				10	
0.50 - 0.99	128	54	20	8	12			4
1.00 - 1.49	24	22	22	6	4	6	2	2
1.50 - 1.99	9	7	3	4		1		
2.00 - 2.49	6	5	2	1	2			1
2.50 - 2.99	2		1			1		
3.00 - 3.49		2					1	1
3.50 - 3.99					1			
Totals	789	220	138	89	39	8	23	8
Grand total	1,314							

Table 2.--Maximum recorded peak discharges

Drainage	Drainage area	Date	Peak discharge
	Sq.miles		c.f.s.
Cuyama River	902	March 3, 1938	17,300
Huasna River	119	February 11, 1938	11,400
Sisquoc River near Sisquoc	282	February 8, 1932	6,240
Sisquoc River near Gary	442	January 23, 1943	13,000
Santa Maria River	1,763	March 5, 1941	14,700

Table 3.--Equations relating peak discharges and sediment production from watersheds to their causes 1/

Number	Equation	Number of data	Correlation coefficient	Standard error of estimate
a) 2/	$\log Q = 2.062 + 1.722 \log P_1 + 1.702 \log aP_{21}$	--	--	--
b) 3/	$\log Q = 1.293 + 1.082 \log A + 1.870 \log P_1 + 0.474 \log aP_{21} - 0.852 \log C$	127	.942	± .301
c) 3/	$\log e_D = 1.041 + 0.866 \log q + 0.370 \log A_{ch} - 1.236 \log C$	23	.953	± .183
d)	$\log e_D = 4.774 + 0.945 \log q_m^{.866} - 3.717 \log C$	8	.871	± .252
e) 3/	$\log e_D = 2.161 + 0.071 \log A + 1.619 \log P'_1 + 0.410 \log aP'_{21} + 0.370 \log A_{ch} - 1.974 \log C$	--	--	--
f)	$\log e_D = 2.092 + 0.941 \log PE_2 - 1.980 \log C$	13	.680	± .326
g)	$\log e_D = 0.812 + 0.866 \log q - 1.236 \log C$	--	--	--
h)	$\log e_D = \log RE/100 + 0.812 + 0.866 \log q - 1.236 \log C$	--	--	--
i)	$\log E_s = 5.815 - 1.641 \log C + 0.0146\, S/C$	14	.911	± .245
j)	$\log e_D = 1.678 + 1.120 \log PE_2 - 2.418 \log C + 0.0183\, S/C$	13	.732	± .319
k)	$\log E_s = 3.561 - 2.093 \log C + 2.210 \log S/C$	14	.914	± .242

1/ For definitions and units of variables see table 4.

2/ P_1 and aP_{21} are Santa Maria (city) data, used as an index only; equation applies to Huasna watershed only.

3/ From: Trans. Amer. Geophys. Union 30(4): 567-584, 1949.

Table 4.--Definition, units, and ranges in variables

Symbol	Variable	Units	Range
Q	Momentary peak discharge from a watershed during the storm	c.f.s.	5 - 90,000
e_D	Sedimentation in reservoir	af/sq mi/yr	0.3 - 36.0
E_s	Average suspended sediment content of streamflow	p.p.m.	3,900-192,300
P_1	Maximum 1-day precipitation during a storm	inches	0.2 - 20.0
P'_1	Maximum 1-day precipitation for maximum storm of a year	inches	
aP_{21}	21-day precipitation antecedent to storm maximum 1 day	inches	0.3 - 23.0
aP'_{21}	21-day precipitation antecedent to maximum 1-day of maximum storm of a year	inches	
A	Watershed area	sq. miles	1.5 - 1,763
C	Average cover density on watershed	percent	2.0 - 72.4
A_{ch}	Area of main channel of the watershed	ac/sq.mile	1.7 - 9.7
q	Maximum yearly peak discharge	c.s.m.	10 - 550
$q_m^{.866}$	Mean of maximum yearly peak discharges to .866 power	--	8.8 - 59.9
PE_2	Average precipitation effectiveness, $1.619 \log P_1 + 0.410 \log aP_{21}$	inches^2	0.82 - 1.48
RE	Relative erodibility, antilog $[\bar{1}.678 + 0.018\ S/C]$ Gibraltar taken as 100	--	41 - 3,746
S/C	Suspended silt + clay/colloids after Middleton	100%/%	31.6 - 138.8
DR	Suspended silt + clay/ultimate silt + clay after Middleton	%/%	17.1 - 46.9
ER	DR x moisture equivalent/colloids	%/%	10.5 - 44.5
P_1/C	Joint variable of P_1 and C (nonsignificant)	--	
P_1-aP_{21}	Joint variable of P_1 and aP_{21} (nonsignificant)	--	
A/C	Joint variable of A and C (nonsignificant)	--	

Table 5.--Estimated peak discharge frequencies from Santa Maria watersheds for various watershed conditions

Sub water-shed name	Area	Discharge events	Peak discharges for "present" watershed conditions for selected recurrence intervals--years 1/ 100	20	5	2	Condition	Factors to convert discharges to 2/ Total program
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Sq.mi.		C.f.s.	C.f.s.	C.f.s.	C.f.s.		
Cuyama	912	Max.yearly	46,704	15,568	4,226	1,068	wo/program	1.224
		All	46,704	18,237	5,894	2,613	w/program	.870
Upper Cuyama	410	Max.yearly	33,858	10,454	2,376	428	wo/program	1.291
		All	--	--	--	--	w/program	.802
Sisquoc	442	Max.yearly	83,828	31,987	9,486	2,504	wo/program	1.182
		All	83,828	35,296	12,684	5,350	w/program	.902
Sisquoc	290	Max.yearly	49,095	20,838	7,746	2,673	wo/program	1.116
		All	49,095	21,820	8,728	4,473	w/program	.918
Huasna	119	Max.yearly	33,635	13,780	4,014	1,085	wo/program	1.152
		All	34,395	16,275	5,642	2,333	w/program	.914
Bradley	10.6	Max.yearly	2,680	1,372	536	193	wo/program	1.237
		All	2,680	1,554	643	332	w/program	.910

1/ Discharge frequencies expected for long-term meteorological events and under existing fire protection levels and existing grazing and agricultural use.

2/ These factors times the discharges listed give discharge frequencies for watershed conditions expected within the next 20 years, considering present trends in use and resultant watershed conditions with and without programs. Programs are given in detail in Appendix 5.

Table 6.--Vegetation density recovery rates following fire--by cover types for various geologic origins of soil parent materials

Cover type	Geology	Minimum cover density	Maximum cover density	Recovery rate (k) 1/
Oak chaparral	Metamorphic	0	90	0.156
	Igneous	0	80	0.139
	Sedimentary	0	65	0.152
Pure chamise and chamise sage	Metamorphic	0	60	0.110
	Sedimentary and igneous	0	50	0.058
	Anorthosite	0	40	0.037
Chamise-manzanita and chaparral	Metamorphic	0	80	0.123
	Igneous	0	75	0.116
	Sedimentary	0	65	0.112
High elevation chaparral	Metamorphic	0	80	0.138
	Sedimentary and igneous	0	70	0.143
Oak woodland (Quercus chrysolepis)	All	0	90	0.263
Oak woodland (Quercus agrifolia)	All	30	40	0.105
Desert chamise and chaparral	Metamorphic	0	65	0.100
	Igneous	0	60	0.094
	Sedimentary	0	30	0.080
Coastal sage	All	0	40	0.153
Desert sage	All	0	30	0.100
Semidesert chaparral	All	0	30	0.051
Pinon juniper	All	10	25	0.074
Timberland chaparral	All	0	50	0.054
Semibarren	Metamorphic	0	20	0.093
	Sedimentary and igneous	0	20	0.053
Conifers	All	50	50	.000

1/ Vegetation density recovery following fire, where if C_t is the cover density "t" years after a fire, C_{Min} is the minimum cover density after a fire, C_{Max} is the maximum change in cover density attained in about 40 years after a fire, t is the years after a fire, k is the constant representing the recovery rate, and e is the base of the natural logarithms; then C_t may be determined from the growth equation $C_t = C_{Min} + C_{Max}(1-e^{-kt})$.

Table 7.--Periodic sedimentation measurements of some reservoirs and associated discharge storm and watershed cover variables

Watershed name	Area	Period	Sedimentation	Mean $q^{.866}$	Average cover density 1/	Average log PE_2 2/	Average cover density 3/	Erosion ratios 4/ DR	ER	S/C
	Sq. miles	Water year	AF/sq. mi./yr.							
Gibraltar	219	1921-31	5/0.45	8.8	41.6	0.94	45.2	25.2	21.0	52.8
		1932-34	3.42	27.8	36.4	1.48	36.8			
		1935-36	1.04	9.8	30.3	0.93	30.4			
		1937-38	4.31	59.9	34.0	1.26	33.9			
		1939-40	0.71	5.6	36.5	0.82	36.2			
		1941	3.84	26.3	38.2	1.27	38.2			
		1942-44	1.15	29.2	40.6	1.48	40.5			
		1945-47	0.29	12.5	43.1	1.18	43.5			
Juncal	16	1931-39	2.07			1.18	20.0	19.1	13.4	37.7
		1940-48	1.06			1.24	34.5			
Mono	119	1937	1.68			0.86	33.8	24.4	19.8	50.8
Caliente	40	1938	4.47			1.67	42.3	20.1	14.4	39.4
		1939-48	0.42			1.21	46.0			

1/ Weighted average, weighted on basis of 0.866 power of the maximum yearly discharge associated with each yearly cover density during the deposition period.

2/ Log PE_2 = 1.619 log P_1 + 0.410 log aP'_{21} from equation (e), table 3.

3/ Weighted average, weighted on basis of PE_2 associated with each yearly cover density during the deposition period.

4/ DR, ER, and S/C are respectively Middleton's dispersion and erosion ratios and 100 times the ratio of suspension percent to colloids percent. U. S. Dept. of Agric. Tech. Bull. 178, 1930.

5/ Plus or minus error in original storage capacity measurement--original capacity of 13,746 acre-feet was used.

Table 8.--Average suspended sediment content of stream flow with associated cover density and mean erosion ratios of some south-coastal watersheds, California

Watershed	Area	Average suspended sediment 1/	Cover density	Erosion ratios 2/		
				DR	ER	S/C
	Sq.miles	P.p.m.	Percent			
Cuyama	81	18,300	31.1	29.7	26.2	84.6
Cuyama	410	140,800	35.1	33.0	29.5	92.3
Cuyama	804	43,500	35.9	36.5	30.2	88.5
Cuyama	912	31,000	36.1	35.1	30.5	87.0
Sisquoc	442	11,100	48.7	32.5	28.8	68.9
Santa Maria	1,638	19,400	42.4	33.4	28.9	76.2
Santa Maria	1,763	30,200	42.3	33.6	29.0	78.6
Bradley	10.6	35,000	44.6	42.5	31.6	82.6
Ballinger	30	192,300	27.1	46.9	44.5	138.8
Tepusquet	13	7,600	44.8	22.6	16.2	42.5
Huasna	119	3,900	58.8	28.1	24.0	58.1
Sespe 3/	254	2,370	51.3	17.1	10.5	31.6
Sespe 4/	254	14,100	19.0	17.1	10.5	31.6
Alamo	89	5,300	53.9	32.4	29.5	69.8

1/ Except for the Sespe samples, all samples were taken in the water year 1940-41 by the U. S. Forest Service, Flood Control Survey Division.

2/ DR, ER, and S/C are respectively Middleton's dispersion ratio, erosion ratio, and 100 x the ratio of suspension percent to colloids. U. S. Dept. of Agric. Tech. Bull. 178, 1930.

3/ Before 1932 fire.

4/ Average for first two years after 1932 fire which burned 76 percent of watershed.

Table 9.--Soil Characteristics

Sample number	Geology 1/	Suspended si + cl 2/	Ultimate si + cl	M.E. 3/	Colloids 4/	Clay	Dispersion ratio 5/	Erosion ratio 6/	Suspension x 100 ÷ colloids
		Percent	Percent	Pct.	Pct.	Pct.			
7	Mc	19.5	39.3	11.9	11.3	9.6	49.6	52.2	172.6
5	QP	16.1	37.9	14.5	19.5	13.0	42.5	31.6	82.6
1	Kc	22.4	61.3	26.5	27.5	13.8	36.6	35.2	81.4
8	Mm	14.6	54.5	19.7	24.4	21.6	26.8	21.6	59.8
11	Mm	16.1	74.1	26.8	36.1	38.4	22.7	16.8	44.6
10	Mm	16.5	77.3	27.3	38.3	36.9	21.4	15.3	43.1
4	Mm	12.0	53.5	20.1	31.3	18.0	22.4	14.4	38.3
9	Mm	16.1	70.9	35.2	50.0	26.7	22.7	16.0	32.2
2	Eu	15.2	94.1	23.4	39.0	35.6	16.1	9.6	39.0
3	Eu	5.1	36.2	16.3	31.4	13.7	14.1	7.3	16.2

1/ Geologic symbols in Geologic Map of California, Jenkins, 1938.

2/ Middleton's silt and clay, U. S. Dept. of Agric. Tech. Bull. 178, 1930.

3/ Moisture equivalent.

4/ Colloids after method W. O. Robinson.

5/ Middleton's dispersion ratio.

6/ Middleton's erosion ratio.

Physical determinations of the soils were made under the guidance of Professor G. B. Bodman, University of California, Soils Department.

Table 10.--Geologic distribution in selected watersheds of the Santa Maria and Santa Ynez drainages, with calculated average erosion ratios

Watershed name	Area	Geologic types, percent of watershed area 1/ Kc-Ks	Eu	Ø	Mm-Mu	Mc	Qt-Qp	Misc.	Erosion ratios 2/ DR	ER	S/C
	Sq.mi.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.			
Gibraltar	219	39.4	41.8		7.2			11.6	25.2	21.0	52.8
Juncal	16	18.8	81.2						19.1	13.4	37.7
Mono	119	34.4	43.5		9.9			12.3	24.4	19.8	50.8
Caliente	40	17.5	67.5		15.0				20.1	14.4	39.4
Sespe	254		52.4	28.9	8.0			10.7	17.1	10.5	31.6
Ballinger	30					62.5	37.5		46.9	44.5	138.8
Cuyama	81		50.6			32.9	7.1	9.5	29.7	26.2	84.6
Tepusquet	13			14.3	85.7				22.6	16.2	42.5
Huasna	119	41.8			55.3			2.8	28.1	24.0	58.1
Sisquoc	442	54.3			30.5		6.1	8.9	32.5	28.8	68.9
Sisquoc	290	68.8		2.8	26.3			2.1	32.4	29.6	70.0
Cuyama	912	15.1	14.2	2.2	7.6	17.1	19.1	24.6	35.1	30.5	87.0
Cuyama	410	2.8	27.8	2.8	6.9	30.1	10.4	19.2	33.0	29.5	92.3
Bradley	10.6						100.0		42.5	31.6	82.6
Alamo	89	60.7		5.6	24.7			9.0	32.4	29.5	69.8
Santa Maria	1,638	31.2	7.9	1.5	20.3	9.5	12.3	17.3	33.4	28.9	76.2

1/ Symbols are standard geologic symbols, and areas are from Geology Map of California, Jenkins, 1938.

2/ DR, ER, S/C are respectively Middleton's dispersion ratio, erosion ratio, and the 100 x ratio of suspension percent to colloids, U. S. Dept. of Agric. Tech. Bull. 178, 1930.

Table 11.--Average erodibility of soils of watersheds, estimated average annual sediment production for various watershed conditions, and "design" storm sedimentation

Watershed name	Area	Erosion constant 1/	Relative erodibility 2/	"Present" sedimentation rate 3/	Condition	Changes in sedimentation under future uses	Sediment reduction 4/	Design sedimentation 5/
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Sq.mi.	AF/sq. mi./yr.		C.y./sq. mi./yr.		C.y./sq. mi./yr.	Percent	C.y./sq. mi./yr.
Gibraltar	219	441	100	1,500				
Huasna	119	551	125	1,407	wo/program	+566		
					w/program	-265	42.1	18,400
Sisquoc	442	869	197	1,860	wo/program	+895		
					w/program	-383	46.4	31,000
Sisquoc	290	910	206	2,198	wo/program	+626		
					w/program	-387	35.9	31,300
Cuyama	912	1,864	422	1,653	wo/program	+1,002		
					w/program	-451	54.7	21,400
Cuyama	410	2,332	529	3,209	wo/program	+2,625		
					w/program	-1,274	66.8	49,500
Bradley Canyon	10.6	1,550	351	7,137	wo/program	+4,668		
					w/program	-1,385	51.3	56,100
Alamo	89	908	206	-	wo/program	--		
					w/program	--	--	--
Santa Maria	1,638		6/ 314	1,583	wo/program	+1,069		
					w/program	-396	55.2	23,600

Footnotes, contd.

Table 11.--Average erodibility of soils of watersheds, estimated average annual sediment production for various watershed conditions, and "design" storm sedimentation - Contd.

1/ From equation (j); antilog [1.678 + 0.0183S/C].

2/ From values of previous column with Gibraltar expressed as 100.

3/ From average cover conditions expected with present grazing condition and average annual burn percents of 1.44 percent on national forest lands and 0.70 percent for other lands.

4/ Sediment reduction with program expressed as a percent of expected sedimentation without program.

5/ Sedimentation expected from 100-year storm, for the first year after a fire which burned an area equal to one-fourth of the brush area of the watershed.

6/ Obtained by areal weighting of constants of Cuyama (912), Sisquoc (442), Alamo (89), and Huasna (119).

Table 12.--Suspended load samples at two points, Santa Maria River

Date 1941	Time	Stage height	Sediment concentration	Date 1941	Time	Stage height	Sediment concentration
		Feet	P.p.m.			Feet	P.p.m.
Santa Maria River at Suey Bridge				Santa Maria River at Guadalupe Bridge			
3-3	10:15P	2.6	9,900	2-11	10:15A	3.6	18,300
1-24	9:20A	0.7	11,400	3-1	8:15A	4.4	19,200
2-10	10:50A	1.5	12,200	2-11	10:20A	3.6	22,000
2-11	11:25A	1.3	12,700	2-11	10:15A	3.6	22,100
1-22	3:15P	0.6	13,600	2-6	10:20A	3.0	22,800
2-10	10:50A	1.5	15,000	2-11	3:30P	4.0	25,500
2-12	9:00A	1.4	15,500	2-11	3:30P	4.0	26,200
2-17	1:40P	2.25	15,800	2-17	3:25P	5.0	26,200
2-17	4:05P	2.0	16,700	2-12	9:30A	5.3	31,900
3-1	8:00A	2.65	16,800	2-17	3:20P	5.0	32,100
2-6	9:20A	1.5	17,300	2-8	5:15P	4.2	33,200
3-4	9:00A	3.0	21,000	2-12	9:55A	5.3	38,600
1-24	4:40P	2.3	21,200	3-4	5:45P	6.8	38,800
2-17	9:30A	2.7	24,600	1-24	5:45P	3.7	40,500
3-4	8:40A	3.05	24,700	3-4	9:50A	6.7	42,500
3-1	8:45A	2.6	31,600	2-12	9:45A	5.3	42,800
2-11	10:40P	2.85	33,300		Average		30,200
3-4	4:45P	3.05	36,500				
	Average		19,400				

Table 13.--Flow duration, associated suspended sediment concentration, and resultant sediment discharge for Sisquoc River, Bradley Canyon, and Santa Maria River at Guadalupe for periods similar to the 1930-48 period and for present watershed condition.

Flow Duration	Daily Discharge	Suspended Sediment Concentration	Total Flow 1/	Total Suspended Sediment 2/
% days/100	c.f.s.	p.p.m.	1,000 AF/yr.	AF/yr.
A. Sisquoc River (Drainage area 442 sq. mi.)				
.01	2,000	23,000	14.5	260
.01	1,000	11,500	7.2	65
.01	630	9,000	4.6	32
.01	430	5,000	3.1	12
.01	340	3,800	2.5	7
.10	90	1,000	6.5	5
.10	20	100	1.4	0
.75	0	-	0	0
1.00			55.0	381
B. Bradley Canyon (Drainage area 10.6 sq. mi.)				
.01	3/112	26,000	0.81	21.0
.01	36	23,000	0.26	4.7
.01	21	21,000	0.15	2.5
.01	14	20,000	0.10	1.6
.01	9.6	16,000	0.07	1.1
.05	3.6	7,000	0.13	0.7
.05	0.8	3,000	0.03	0.1
.85	0	-	0	0
1.00			1.55	31.0
C. Santa Maria River (near Guadalupe) (After Santa Maria Project installed)				
.01	890	28,400	6.43	143
.01	370	27,400	2.68	57
.01	165	27,000	1.19	25
.01	83	27,000	0.60	13
.01	43	27,000	0.31	7
.01	22	27,000	0.16	3
.01	3	27,000	0.02	0
.93	0	-	0	0
1.00			11.39	248

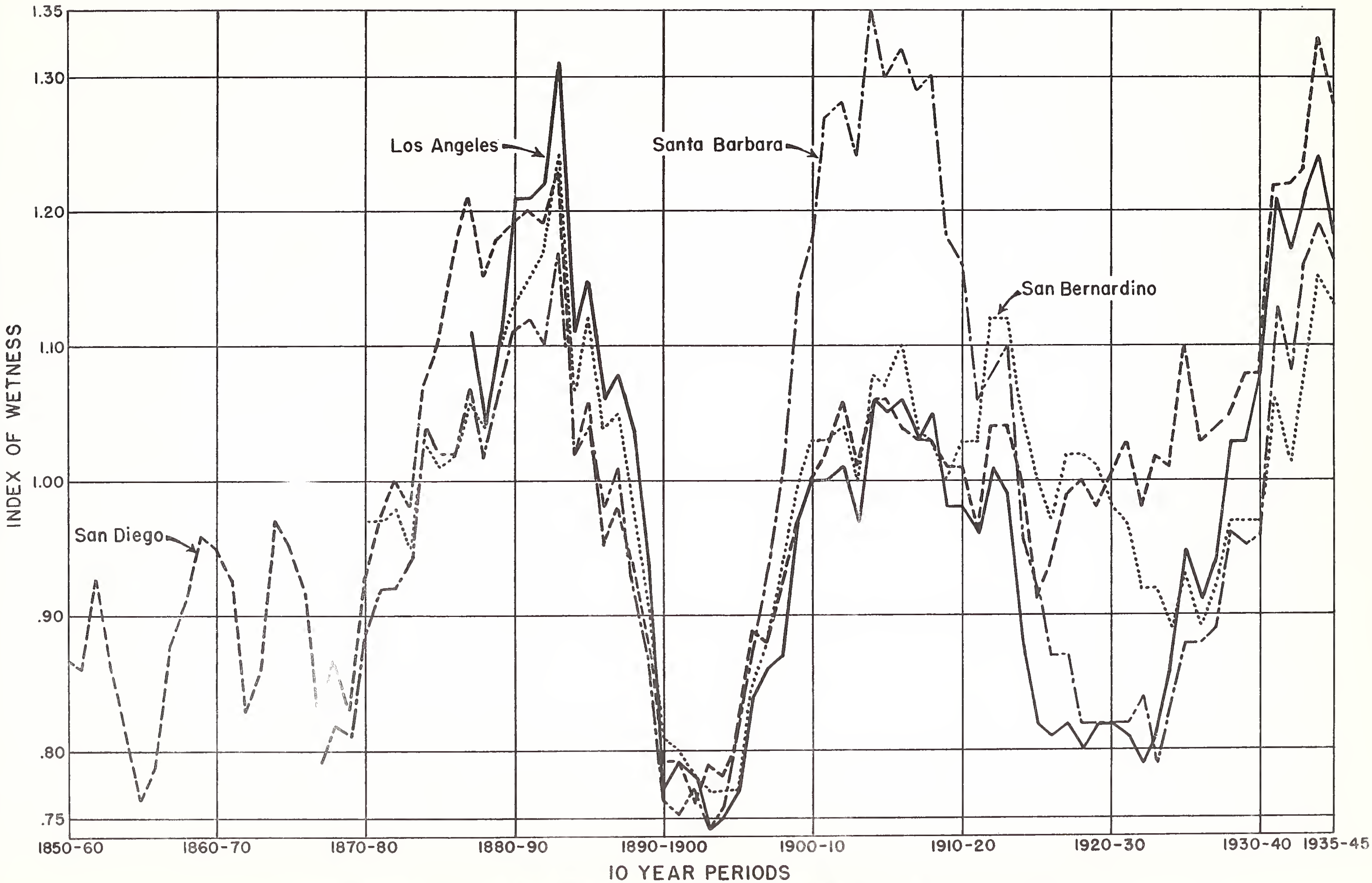
1/ (Col. 1) x (Col. 2) x (365) x (1.98).
2/ (Col. 3) x (Col. 4)/1,280.
3/ Taken as 0.08 times discharges of Huasna River near Santa Maria.

Table 14.--Sedimentation of Vaquero Reservoir under three levels of watershed conditions--present, future without USDA program, and future with USDA program.

Year	Length of Period	Sedimentation Rate: Present	Sedimentation Rate: Future W/O Prog.	Sedimentation Rate: Future W/ Prog.	Conservation Pool Capacity: Present	Conservation Pool Capacity: Future W/O Prog.	Conservation Pool Capacity: Future W/ Prog.	Percolation to Ground Water: Present	Percolation to Ground Water: Future W/O Prog.	Percolation to Ground Water: Future W/ Prog.
		AF/yr.	AF/yr.	AF/yr.	AF	AF	AF	AF/yr.	AF/yr.	AF/yr.
1957					125,000	125,000	125,000			
	23	900	1,446	655				19,600	19,200	19,800
1980					104,300	91,700	109,900			
	10	900	1,446	655				18,400	17,100	19,000
1990					95,300	77,200	103,400			
	9	900	1,446	655				17,700	15,500	18,500
1999					87,200	64,200	97,500			
	8	900	1,446	655				16,900	13,900	18,100
2007					80,000	52,600	92,300			
	25	900	1/ 1,434	655				15,100	9,200	17,000
2032					57,500	16,800	75,900			
	25	1/ 897	1/ 672	655				11,600	1,500	15,100
2057					35,100	0	59,500			
	25	1/ 884	-	653				6,900	0	12,600
2082					13,000	0	43,200			
	25	1/ 520	-	1/ 650				1,300	0	9,600
2107					0	0	27,000			

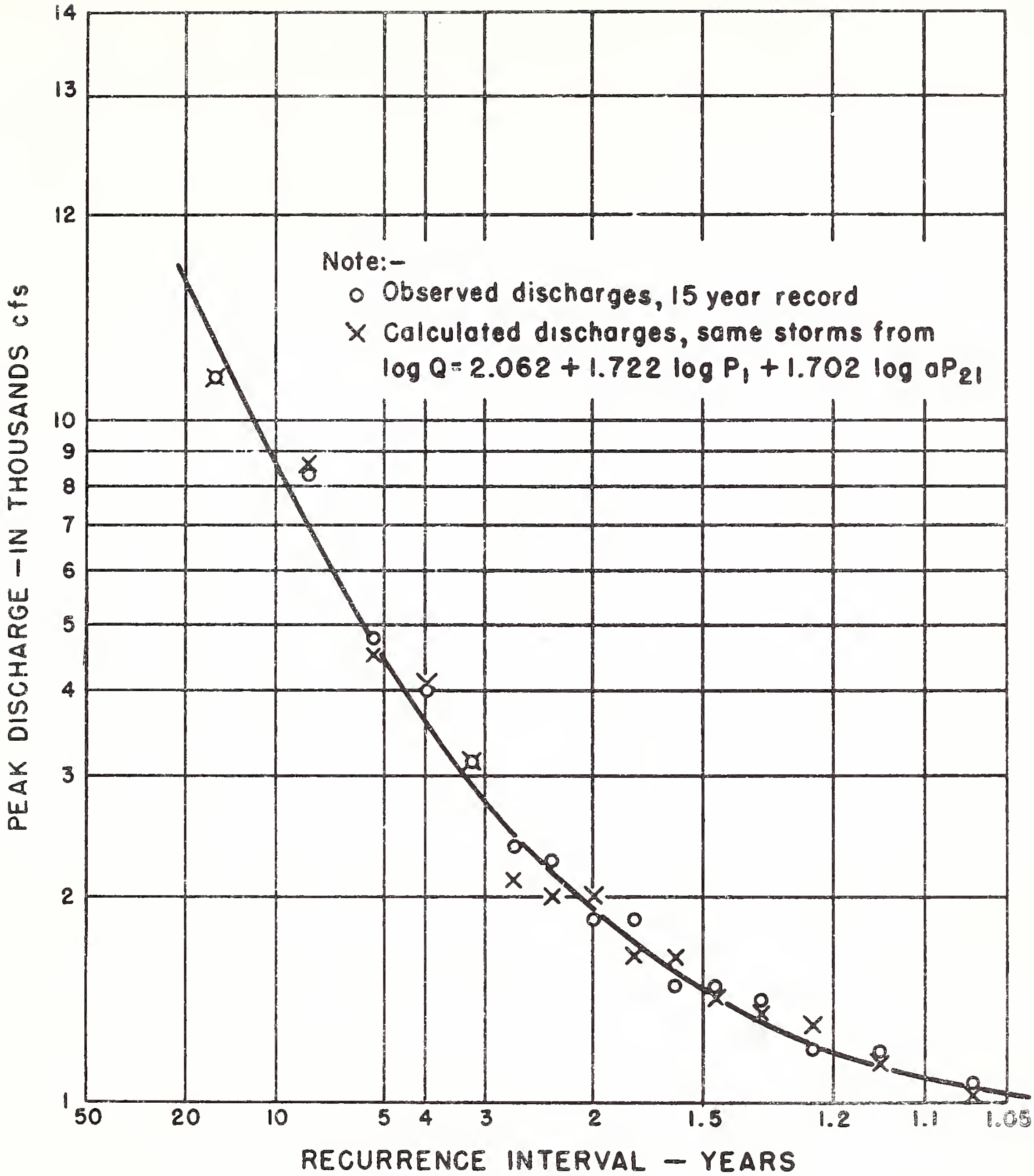
1/ Changes in trap efficiency taken proportional to those given by G. M. Brune, "Trap Efficiency of Reservoirs," Trans. Amer. Geophy. Union, 34(3): 414, Figure 6, 1953.

PLATE TO ACCOMPANY HYDROLOGY APPENDIX — SAN GABRIEL AND SANTA ANA WATERSHED CALIF. — PREPARED JANUARY 8, 1948



PROGRESSIVE 10 YEAR MEAN PRECIPITATION AT SELECTED STATIONS

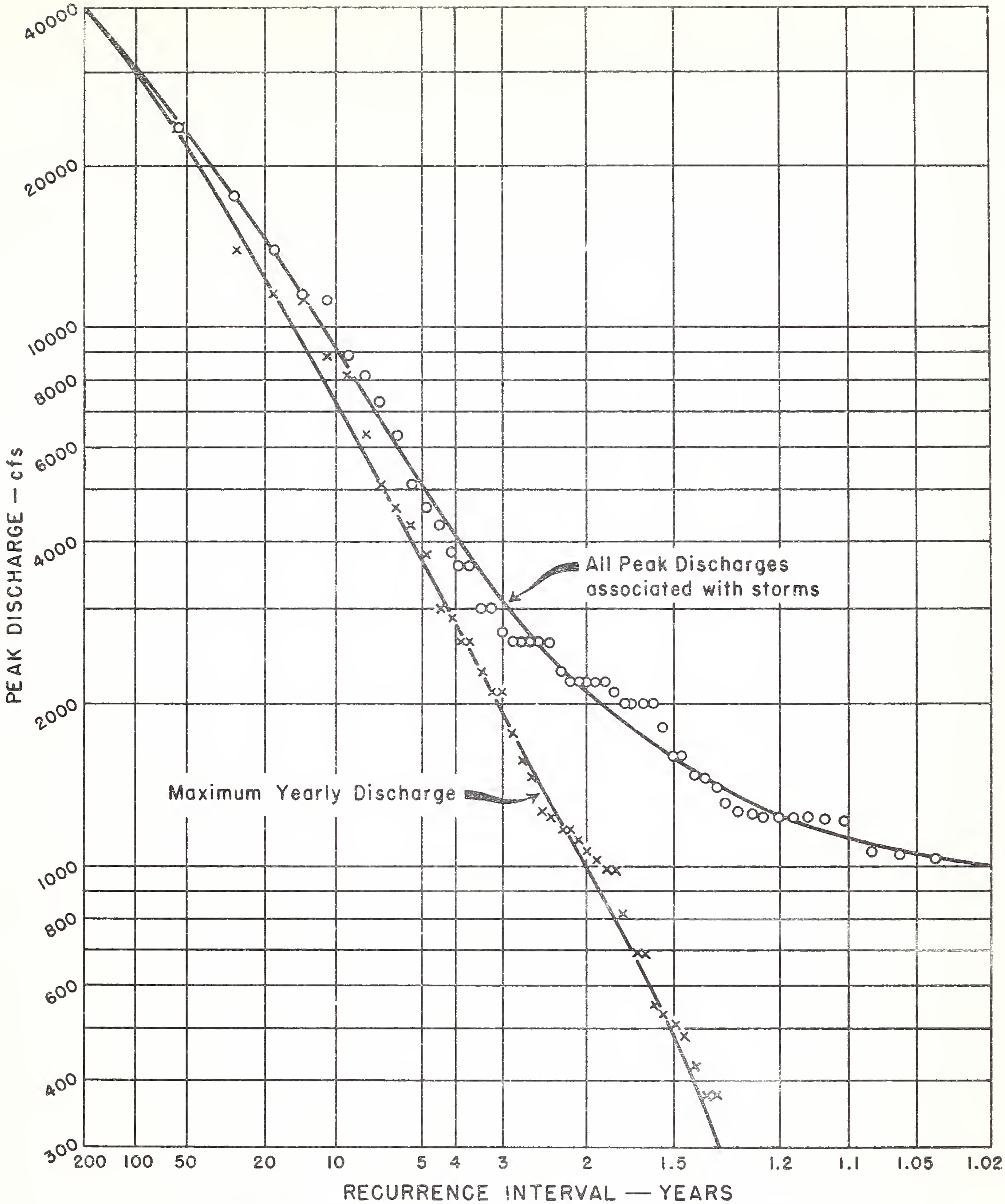
Figure 1



FREQUENCY CURVE – HUASNA

TEST OF RELATIONSHIP
OF OBSERVED TO CALCULATED PEAK DISCHARGES
BY COMPARISON OF FREQUENCY POINTS

Figure 2

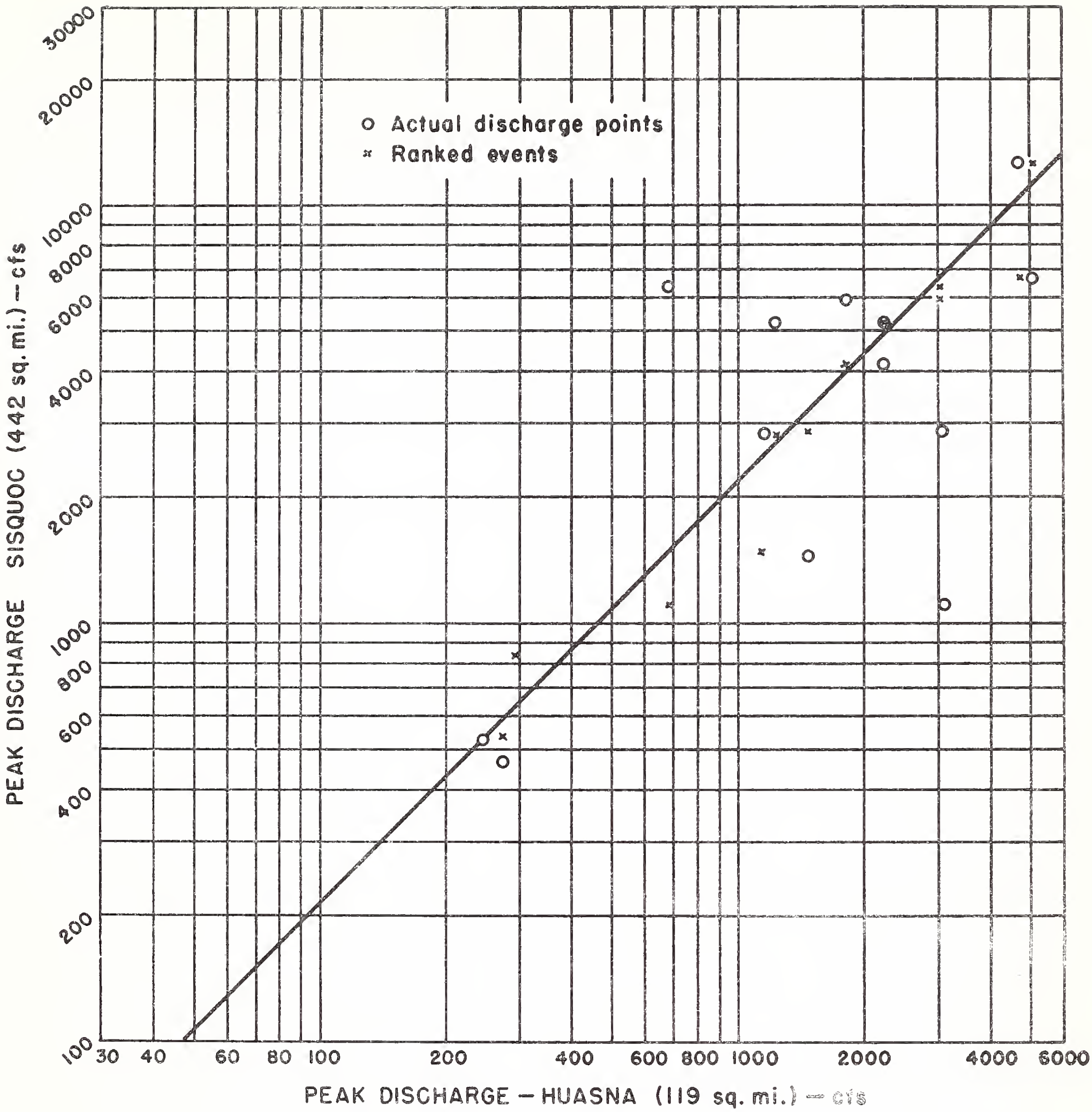


FREQUENCY CURVE — HUASNA

ESTIMATED FREQUENCY OF PEAK DISCHARGES FOR 40-YEAR OLD COVER DENSITY

FACTOR TO CONVERT TO PRESENT = 1.064

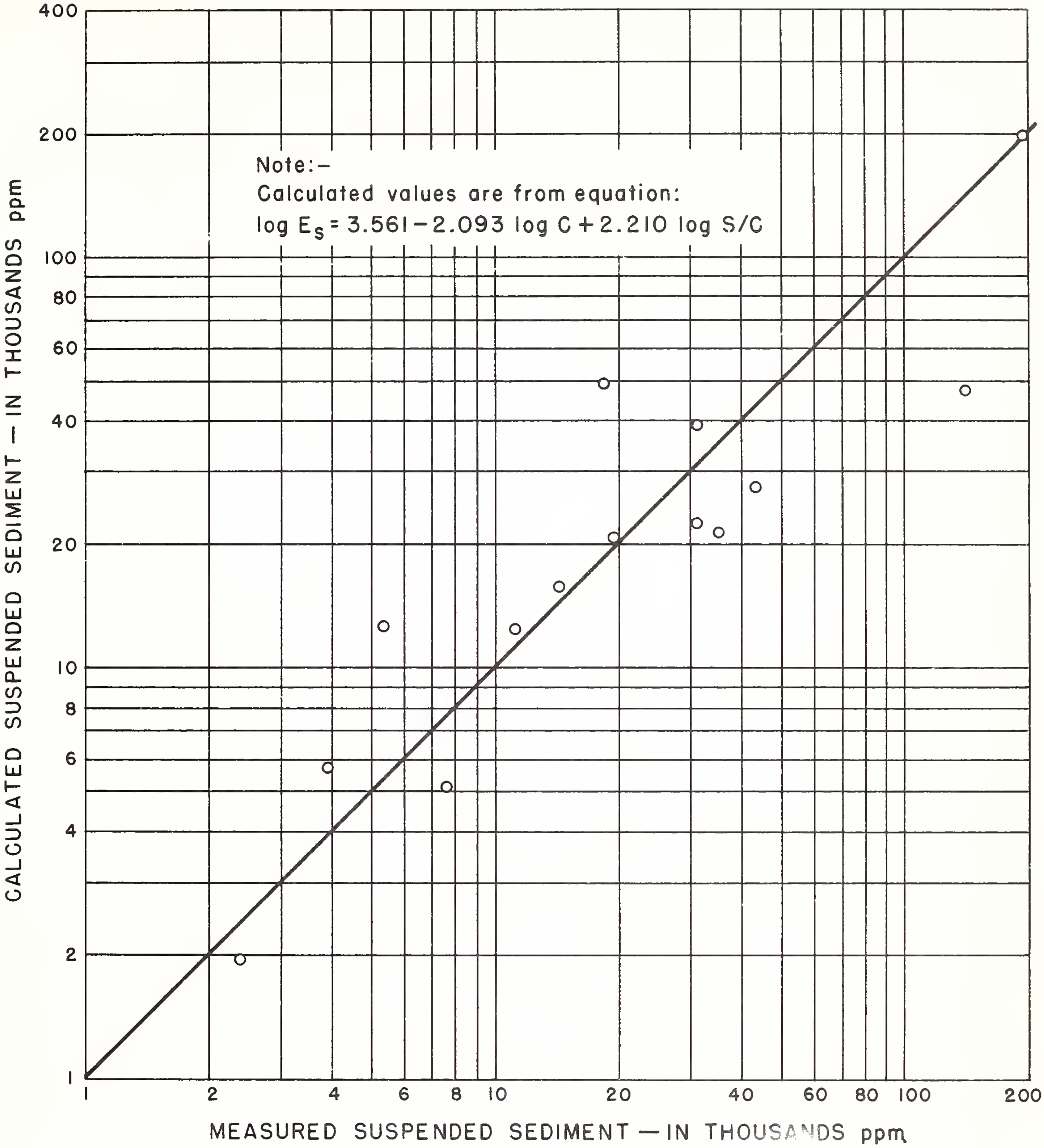
Figure 3



HUASNA — SISQUOC

PEAK DISCHARGE RELATIONSHIP FOR SAME STORM FLOWS CORRECTED TO COMMON BASIS OF 40-YEAR OLD VEGETATION

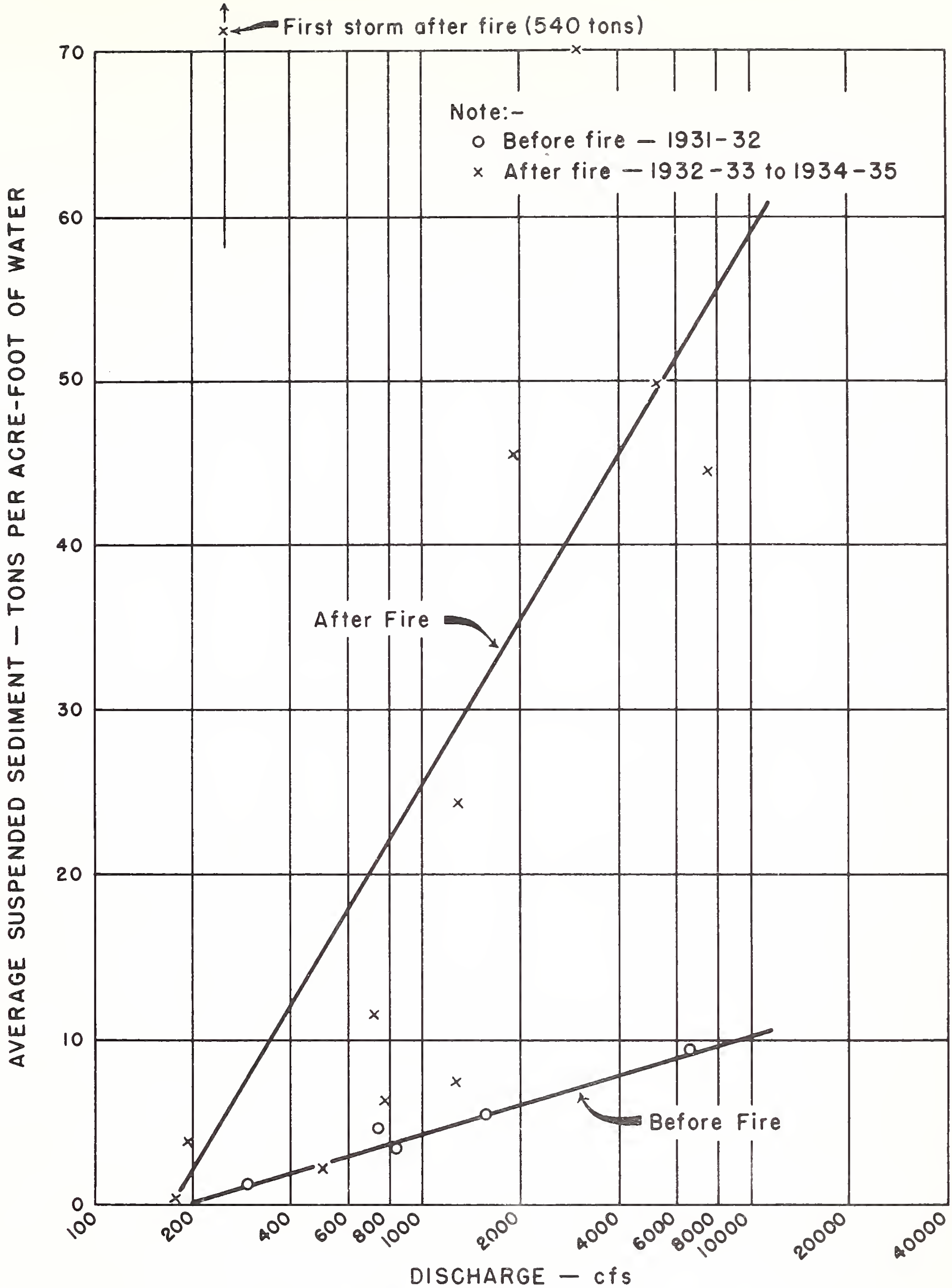
Figure 4



SUSPENDED SEDIMENT

RELATION OF MEASURED TO COMPUTED AVERAGE SUSPENDED SEDIMENT OF STREAMS FOR WATERSHEDS IN AND ADJACENT TO THE SANTA MARIA

Figure 5



SUSPENDED SEDIMENT IN RUNOFF WATER — SESPE CREEK

BEFORE AND AFTER 1932 FIRE

DATA FROM ANNUAL REPORTS
SANTA CLARA WATER CONSERVATION DISTRICT
1931-32 TO 1934-35

SANTA MARIA WATERSHED
CALIFORNIA

Relation Of Vaquero Reservoir
Storage To Increased Percolation

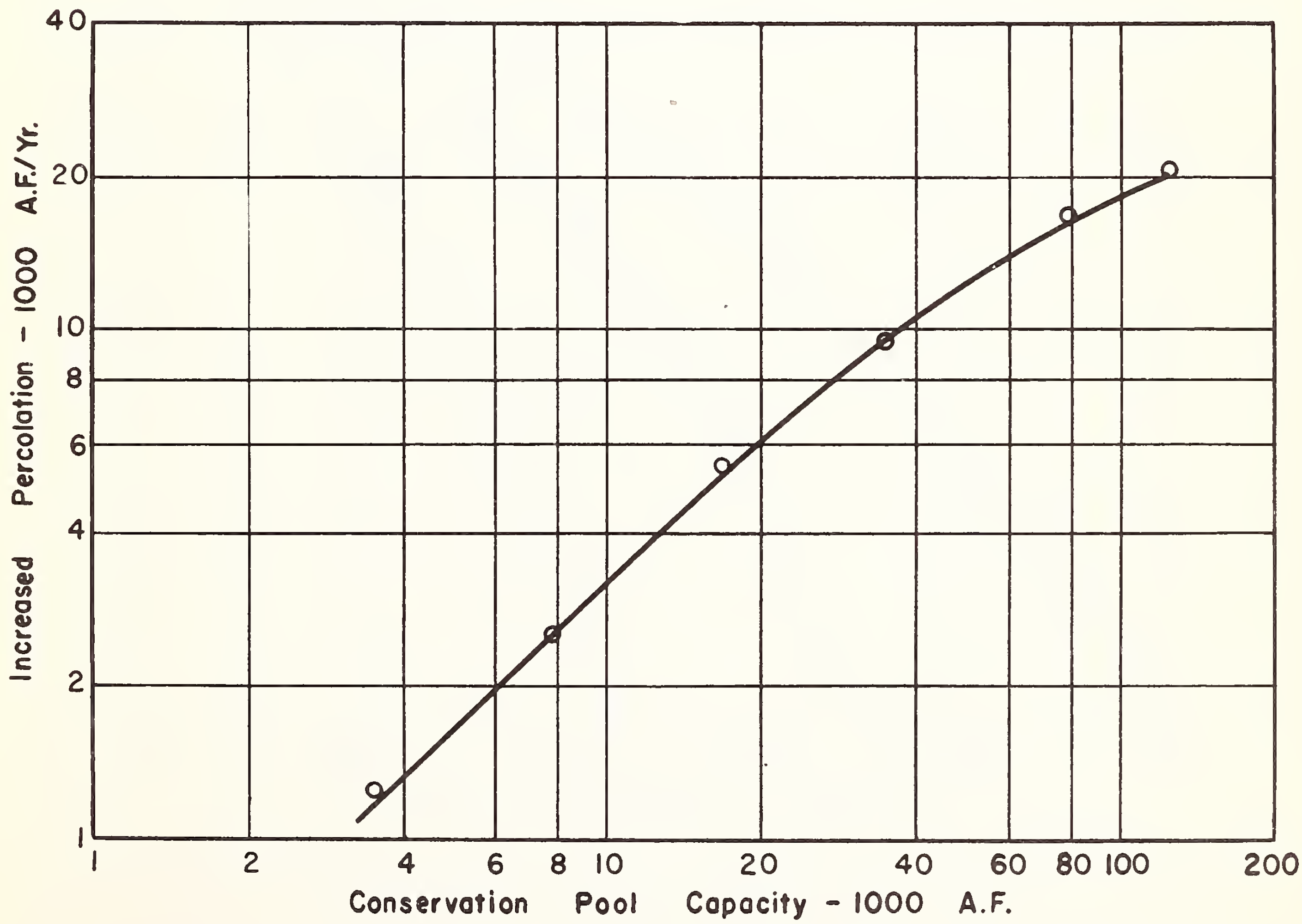


Figure 7

U.S. Dept. Of Agr.
RDS 1953

SOURCE OF DATA: BUREAU OF RECLAMATION

AGR-SCS-PORTLAND, ORE NOV 1953

SANTA MARIA WATERSHED

CALIFORNIA

Age - Yield Relationship Of Vaquero Reservoir For Three Watershed Conditions

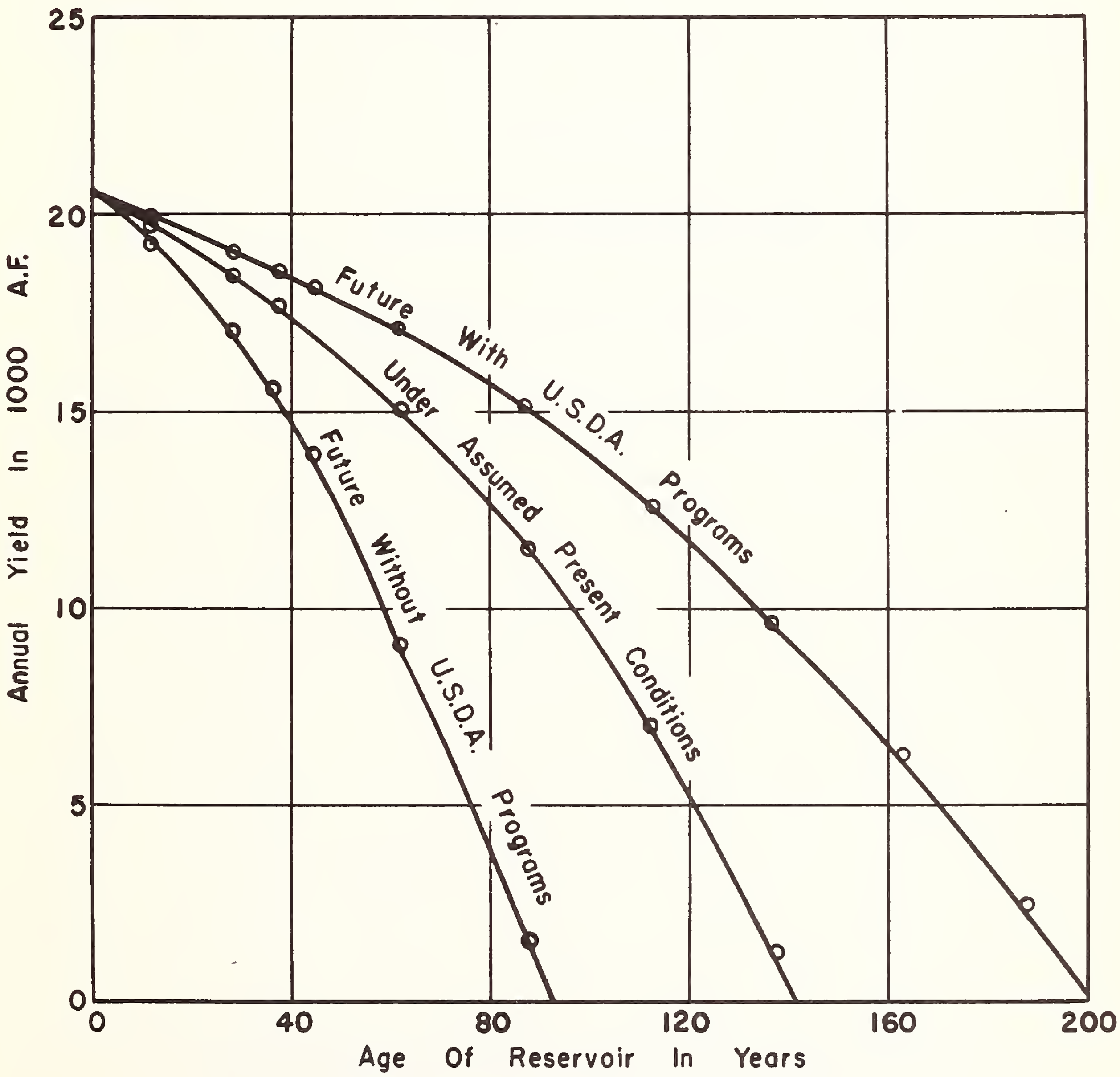


Figure 8

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UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 4

FLOOD AND SEDIMENT DAMAGES

Santa Maria Watershed, California

To accompany report on survey, flood control, Santa Maria Watershed, California, dated June 1950

APPENDIX 4

FLOOD DAMAGES

Santa Maria River Watershed, California

Exact information concerning floods and flood damages in the Santa Maria Valley is very meager as no measurements of river stage, or of discharge, have been made during great floods. Great floods have occurred at wide intervals but none in recent years.

The following tabulation summarizes the historical information on floods in the Santa Maria River watershed.

Table 1.--Flood history of the Santa Maria River, California

Designation number	Season	Source of information	Descriptive notes
1	1825	Statement by John L. Harris Sept. 9, 1937	Prior to the year 1825 the Santa Maria River flowed through the Oso Flaco district to Oso Flaco, which indicates that the flood of 1825 caused the Santa Maria River to change its course and flow into the ocean via Guadalupe.
2	1862	Statement by John F. Dana, Nov. 21, 1928, resident of Nipomo	In 1862, one of the worst floods occurred in the history of this section. Creeks and river beds were widened and much land was ruined. The present location of Santa Maria was a deep lake. The drift or high water mark on the banks of the Santa Maria River was higher than a man's head while on horseback.
3	1878	Statement by A. F. Fugler, Sept. 3, 1937	During the year 1878 the Santa Maria and Sisquoc Rivers washed away 20 acres of Francis Fugler's farm land near Fugler's Point at the confluence of the Cuyama and Sisquoc Rivers.
4	1884	Statement by L. E. Blockman, Sept. 4, 1937	In the Santa Maria Valley during the season of 1884 there were few rainless days from the last days of January through February and March, and the first half of April; and serious washouts occurred.

Contd.

Table 1.--Flood history of the Santa Maria River, California - Contd.

Designation number	Season	Source of information	Descriptive notes
5	1884	Santa Maria Times, Mar. 1884	The Santa Maria River changed its channel and now runs south of the bridge. About 100 feet of north end of the bridge were damaged, and travel was halted.
6	1885	Santa Maria Times, Nov. 21, 1885	A total of 7.13 inches of rain fell during the biggest storm on record; 2.31 inches fell on Tuesday and 3.74 inches on Wednesday. No great amount of damage resulted in the valley; the railroad grade was washed out in various places and the river was impassable.
7	1890	Statement by A. F. Fugler, Sept. 3, 1937	A flood occurred in the Santa Maria and Sisquoc Rivers and washed away 20 acres of farm land near Fugler's Point.
8	1893	Santa Maria Times, Feb. 1893	The Santa Maria River overflowed; serious damage was prevented by wing dams installed by the Pacific Coast Railroad.
9	1897	Statement by L. J. Morris, Aug. 31, 1937	Over half of a leased 80-acre farm and all of his own 40-acre farm were washed out by the river.
10	1909	Report to the Santa Maria Reclamation District by F. C. Finkle, Consulting Engineer, Sept. 3, 1909	During the period of floods from January to March 1909, about 1,000 acres of farming land were carried away. From the highwater marks on two bridges the overflow was calculated to have been about 100,000 c.f.s.
11	1910	War Dept. Survey Rept., Santa Maria River and its tributaries, Calif., Feb. 10, 1939	A flood of great magnitude occurred in the Santa Maria River in March 1910.

Contd.

Table 1.--Flood history of the Santa Maria River, California - Contd.

Designation number	Season	Source of information	Descriptive notes
12	1911	Statement by H.H.Saulesbury, Sept. 9, 1937	During the high flood of 1911, the Santa Maria River washed away approximately 60 acres of good farming land. The bed of the river has been filling up with silt since 1911. Formerly the clearance was about 15 feet under the railroad bridge, now (1937) it is not more than 6 or 7 feet.
13	1914	War Department Survey Report	On the Santa Maria River, bridges were washed away and considerable marginal farm land was destroyed in February 1914 by flood waters.
14	1915	War Department Survey Report	The flood of February 1915 was not as great as the flood of February 1914, but it caused considerable damage to bridges and bank protection works on the Santa Maria River.
15	1927	War Department Survey Report	On January 1927, the Santa Maria River overflowed its banks and flooded the north part of the city of Santa Maria and submerged a considerable area of farm land.
16	1937	War Department Survey Report	In February 1937, a flood occurred on the Santa Maria River with a crest flow estimated by local interests at 35,000 c.f.s. During this flood a considerable area of farm land was overflowed and bridges were damaged.
17	1938	War Department Survey Report	In February 1938, a flood occurred in the Santa Maria River with a crest flow estimated at 38,000 c.f.s. During this flood the losses in the Santa Maria Valley were relatively light, except damage to Suey Bridge.
18	1938	Santa Maria Daily Times, March 1938	Encarnacion Rivas, 41, a WPA worker, was drowned when he drove his car into the Sisquoc River at Gary Bridge. He was apparently unaware that the bridge had been washed out by the flood waters.

As indicated elsewhere in this report, the Bureau of Reclamation and the Corps of Engineers have recommended a comprehensive project for the Santa Maria River to include a reservoir on the Cuyama River at the Vaquero site and levees on the Santa Maria River and Bradley Canyon. This project, if installed, will control nearly all flood damages in the Santa Maria Valley and the city of Santa Maria. Since most damages now occurring in these areas will be eliminated by the Santa Maria Project, the Department of Agriculture survey report does not include damage estimates for this area. All prices at 1947 level except for figures relative to Vaquero Reservoir, which are based on prices representative of the State average for the base period 1939-44 with adjustment wherever deemed necessary to more nearly reflect long-term outlook.

1. Estimate of Flood Damage in the Cuyama Valley

Damage in the Cuyama Valley is to crops, irrigation facilities, farm equipment and buildings, and roads and bridges. Land is lost by bank cutting along the river and scouring when the river leaves its bed and flows across the cropland. After floods recede the land traversed by the floodwaters has to be releveled and recultivated, and when the season permits seeded to new crops.

Irrigation agriculture is of recent development in the Cuyama Valley. At present the major crops are seed potatoes and grains, but these are giving way to other crops. For purposes of damage calculation, it is

Assumed that crop rotations would finally approach those in the Antelope Valley, located about 50 miles to the east. Distribution of land use, beginning in March, is assumed as follows:

Alfalfa	50 percent
Idle 1/	30 percent
Grain	10 percent
Fruit and vegetables	10 percent

It is estimated that the following acreage would be flooded by the discharges given below:

40,000 c.f.s.	4,300 acres
20,000 c.f.s.	3,300 acres
10,000 c.f.s.	1,450 acres
3,000 c.f.s.	150 acres

The estimated damages for these four flood sizes are given in table 4.

Table 4.--Estimated future direct and indirect damages for floods of different magnitudes in the Cuyama Valley

Item	Direct damage	Indirect damage	Total
	Dollars	Dollars	Dollars
40,000 c.f.s.			
Agriculture, including buildings	461,900	31,200	493,100
Roads and bridges	130,000	39,000	169,000
Total	591,900	70,200	662,100
20,000 c.f.s.			
Agriculture, including buildings	318,200	24,200	342,400
Roads and bridges	55,000	16,500	71,500
Total	373,200	40,700	413,900
10,000 c.f.s.			
Agriculture, including buildings	135,600	10,800	146,400
Roads and bridges	25,000	5,000	30,000
Total	160,600	15,800	176,400
3,000 c.f.s.			
Agriculture, including buildings	14,700	700	15,400
Roads and bridges	1,500	200	1,700
Total	16,200	900	17,100

1/ Idle cropland is defined as land not in crop at time of flood. It is not waste land.

The damage for these four flood sizes plotted gives the damage discharge curve. Table 5 of Appendix 3 gives the frequencies of given discharges. From these two sets of data the damage frequency curve is developed. Calculation of the annual loss is shown in table 5 below.

Table 3.--Damage frequency and average annual damages, Cuyama Valley

Frequency	Discharge	Damage	Damage times number of events
	C.f.s.	Dollars	Dollars
.5	66,000	760,000	760,000
1.5	34,200	607,000	607,000
2.5	24,600	485,000	485,000
3.5	18,400	407,000	407,000
4.5	14,700	315,000	315,000
7.5	9,200	157,000	785,000
15.0	4,300	37,000	370,000
25.0	2,100	10,000	100,000
Total			3,829,000
Average annual			38,300

2. Estimation of Flood Damages from Bradley Canyon

Damage from Bradley Canyon is predominantly to crops, cropland, and roads on the Santa Maria floodplain. These damages will largely be eliminated by the proposed levees of the Santa Maria Project. Some damage to roads and loss of land by gullying and bank cutting occurs above the proposed levee protection area. These upstream annual damages are estimated to be $1,100.

3. Estimation of flood damages in small overflow areas south and north of the Santa Maria Valley

The areas on the south side of the valley are: Gary Canyon, Guadalupe Lake, Telephone Road, and Solomon Canyon. Damage is caused from small canyon flows and deep gullies. Damage from Gary Canyon is to truck crops and roads. In the other areas the damage is predominantly to low-value crop and pasture land and roads. The average annual damage from this group is estimated at $2,000.

On the north side of the valley considerable damage is done to the road and cropland on the Santa Maria Mesa. The flows come from small canyons and gullies in the steep hills above the mesa and from eroding cropland. Damages are estimated at $1,800 a year. They include destruction of the road by cutting, debris deposition, and loss of rich, dry-cropped agricultural land by gully cutting.

4. Estimation of Sedimentation Damages (Vaquero Reservoir)

The effectiveness of the proposed Vaquero Reservoir in saving water for percolation to ground water is dependent on the capacity of the conservation pool. Initially this pool will have a capacity of 125,000 acre-feet. However, the capacity of the pool is subject to depletion by sedimentation. The average annual damages due to this sedimentation were evaluated as follows:

(1) The present value of additional irrigation as a result of an increase in ground water was determined over the life of the reservoir, assuming no sedimentation. This was done by applying the relationship of the pool capacity to the percolation to ground water and to the additional acreage irrigated, as developed by the Bureau of Reclamation. The procedures and relations employed by the Bureau of Reclamation were then used to arrive at the benefit of the additional ground water (table 4). The only change was to carry the evaluation through for 200 years with no decrease in ground water recharge as a result of sedimentation.

(2) From the evaluation of program effects on expected sedimentation of Vaquero Reservoir in Appendix 3 and Appendix 6, and from the calculations in step 1 above, the following table was made to summarize the average annual damage to Vaquero Reservoir:

Period	Present Worth of Additional Irrigation			Average An. Damage
	With No Sedimentation	W/O Program	Difference	
50-year	$51,852,000	$46,116,000	$ 5,736,000	$202,300
100-year	67,899,000	52,042,000	15,857,000	433,100
200-year	73,900,000	52,042,000	21,858,000	548,600

Table 4.--Determination of Irrigation Benefits Assuming No Sedimentation of Vaquero Reservoir

Years of Reservoir Operation	Annual Ground Water Yield 1/ Acre-Feet	Additional Acreage Irrigated 2/ Flood Plain 1000 A	Additional Acreage Irrigated 2/ Bench Land 1000 A	Direct Benefit 3/ $1,000	Total Benefit 4/ $1,000	Present Worth Factor 2½%	Present Worth $1,000
1- 10	20,300	8.8	1.2	820.4	1,567.8	8.752	13,721
11- 20	"	10.6	2.0	1,017.6	1,944.6	6.837	13,295
21- 30	"	"	"	"	"	5.341	10,386
31- 40	"	"	"	"	"	4.172	8,113
41- 50	"	"	"	"	"	3.259	6,337
51- 60	"	"	"	"	"	2.547	4,953
61- 70	"	"	"	"	"	1.989	3,868
71- 80	"	"	"	"	"	1.554	3,022
81- 90	"	"	"	"	"	1.214	2,361
91-100	"	"	"	"	"	0.948	1,843
101-110	"	"	"	"	"	0.740	1,439
111-120	"	"	"	"	"	0.578	1,124
121-130	"	"	"	"	"	0.451	877
131-140	"	"	"	"	"	0.352	684
141-150	"	"	"	"	"	0.275	535
151-160	"	"	"	"	"	0.215	418
161-170	"	"	"	"	"	0.164	319
171-180	"	"	"	"	"	0.131	255
181-190	"	"	"	"	"	0.103	200
191-200	"	"	"	"	"	0.080	156

1/ Data from Plate 6, Bureau of Reclamation Report, Santa Maria Project, Southern Pacific Basin, California, H. D. 217, 83rd Congress, First Session.

2/ 0.50 times Annual Water Yield during first 10 years; 0.62 times Annual Water Yield 11th-200 years.

3/ $86 times Additional Acreage Irrigated on Flood Plain plus $53 times Additional Acreage Irrigated on Bench Lands.

4/ Using the Bureau of Reclamation Conversion of Direct to Total Benefits: Total Benefits = Direct Benefit times 1.911.

50-year total		51,852
100 "	"	67,899
200 "	"	73,900

5. Summary of Damages for the Santa Maria River Drainage

Average annual damages in this watershed have been calculated to be $591,800. They are summarized in table 5.

Table 5.--Summary of average annual damages, Santa Maria River watershed

Damage area	Average annual damage 1/
	Dollars
Vaquero Reservoir	548,600
Cuyama Valley	38,300
Bradley Canyon	1,100
Canyons south of Santa Maria Valley	2,000
Canyons north of Santa Maria Valley	1,800
Total	2/ 591,800

1/ In estimating these damages it was assumed that the present monetary level of watershed protection will continue. It is further assumed that as use of the watershed increases, due to increased population and industrial growth, fire and other hazards will increase. The present monetary level of protection will be inadequate to cope with these new hazards and pressures so that watershed conditions are expected to deteriorate in the absence of the USDA program outlined herein.

2/ Does not include damages in the Santa Maria project area.

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 5

THE WATERSHED TREATMENT PROGRAM IN RELATION TO THE FLOOD PROBLEMS

Santa Maria River Watershed, California

To accompany report on survey, flood control,
Santa Maria River Watershed, California, dated June 1950

APPENDIX 5

THE WATERSHED TREATMENT PROGRAM IN RELATION TO THE FLOOD PROBLEMS

Santa Maria River Watershed, California

The contribution of the Department of Agriculture toward the alleviation of flood problems is aimed at the improvement of soil-cover relationships which are essential to the attainment of optimum infiltration capacities and minimum soil losses. The recommended remedial program is designed to accomplish reductions in flood flows and the prevention of soil erosion on the flood problem areas. The land problems influencing floods have been investigated according to major use classes and remedial measures recommended for each.

Of the total land area in the Santa Maria River watershed, 1,356 square miles, or 72 percent, are classed as areas of significant contribution to the flood problem. Eighteen percent or 338 square miles are classed as areas which are not now, but may become, significant contributors to the flood problem due to land use changes or conditions now under way or expected in the future. The remaining 10 percent of the watershed, 179 square miles, does not constitute an important present or potential contributor to the flood problem.

Land problems influencing floods can be segregated into three broad groups, namely, range, forest, and cropland. Fundamentally, the problems of these three land-use groups are identical and interrelated.

Wildland Problems and their Solution

Wildland Problems.--The total area of inflammable cover in the Santa Maria River watershed amounts to about 1,074,300 acres. The principal task on this land is maintenance and improvement of this protective cover to reduce excessive runoff and erosion, especially on the steep mountain slopes.

The fire history of the watershed during the past 100 years is one of severe and repeated burns. Approximately 25 percent of the watershed, exclusive of the cultivated area, has been burned over one or more times during the past 20 years. Areas burned in individual years vary greatly from the average as illustrated by the year 1922 with a burned area of about 80,000 acres and the year 1941 with no burned acreage. Again in 1932 the total area burned in the Santa Maria drainage was relatively small, about 4,200 acres. In the same year the adjoining Santa Ynez watershed experienced a major conflagration which denuded 218,000 acres.

The present level of fire protection has restricted the average annual burn to about one percent of the burnable area. Assuming continuation

of this current level of protection with increasing risk and hazard, the future rate of burn can be expected to increase also and may well occasion at least one major conflagration of at least 50,000 acres in the next 20-year period. This further assumes that watershed conditions will not alter greatly from those existing during the past 20 years when a large part of brush- and forest -covered watershed has been inaccessible with corresponding limited public use.

Future use can be expected to increase greatly because of industrial and recreational demands. The recent development of the newly discovered oil field in the Cuyama Valley indicates that this field is one of the most important to be discovered in California in the last 20 years. At present it is fifth among this state's oil-producing areas. The application for oil and gas leases has mounted to boom proportions which is indicated in part by the number of applications on Los Padres National Forest lands in this watershed. Prior to January 1, 1949, a total of 302 applications had been filed on national forest lands. Within a 16-month period from January 1, 1949, to May 10, 1950, 1,467 oil lease applications were filed on about 500,000 acres of public land. One company alone has brought in its 204th producing well in this area. This same company expects to have at least 150 more wells producing in this field within another year.

Early in 1950 Cuyama Valley Community, Inc. was formed to set up a planned community for the growing number of workers in this field.

The size and value of the Cuyama oil field indicates that extensive exploratory work and development can be expected throughout much of the upper watershed. This same area, until recently considered remote and to a large extent inaccessible, may soon become intensively used. Such use is inevitably accompanied by corresponding increases in fire risk and fire occurrence.

Even before the discovery of the Cuyama oil field, the number of forest users had increased markedly as indicated in table 1.

Table 1.--National forest users for period 1911 to 1949

Period	Number of all classes of forest users
1911-1925 (average annual for period)	9,870
1926-1930 (average annual for period)	68,500
1935	109,500
1940	244,000
1945 (restricted use during war years)	135,500
1949	305,500

A related problem peculiar to the wildland area involves the heavy use of the forest lands during the hunting season which at present is coincident with the period of highest fire danger.

As a result of increased development and population growth a conservative estimate of future annual use is about 360,000. Past experience shows that increased use invariably results in an increased number of fires regardless of the prevention effort. Number of fires occurring in relation to use is given in table 2.

Table 2.--Comparison of forest use and number of man-caused fires

Year	Average annual number of users	Average number of man-caused fires	Number of users per man-caused fire
1911-25	9,870	19.5	506
1926-30	68,500	21.2	3,231
1931-35	96,360	25.2	3,823
1936-40	192,710	25.0	7,708
1940-45	(Inadequate records)		
1947-49	267,180	27.0	9,895

From these records, it is to be expected that for every 10,700 users in the near future there will be at least one fire.

Subsequent analysis of these data indicates that (1) the estimated 360,000 annual users will bring about an incidence rate of one fire for every 10,700 users; (2) this rate will in turn cause about 33 fires annually under the present level of protection; and (3) this number of fire starts will increase the average annual rate of burn to about 3 percent.

Proposed Solution to Wildland Problems.--Intensification of the present level of protection is essential for the 1,074,000 acres of steep brush- and tree-covered watershed which has a high runoff and erosion potential. Adequate protection for flood-control purposes has been defined as that required to reduce the average annual burned area to about 0.2 percent. This objective aims at the control of fires while they are small, holding all fires to a minimum size and hold potential conflagrations to a maximum size of about 6,000 acres.

The areas now protected by various agencies are shown in table 3.

Table 3.--Areas protected by Federal, State, and County agencies, Santa Maria River watershed

Agency	Protection area
	Acres
U. S. Forest Service	634,950
California Division of Forestry	192,230
Santa Barbara County Forestry Dept.	247,150
Total	1,074,330

Present protection and control techniques must rely upon a good system of fire roads, trails, and landing fields. Motorized equipment, modern communications, and aircraft are needed. There must be patrol stations, fire lookouts, and above all, a well-trained prevention and suppression crew. The protection and control system is not static. Therefore, the recommended additions to the present protection plant may need revision or modification as new techniques and fire control devices are developed. The additional facilities and personnel needed to intensify fire protection commensurate with flood control objectives are as follows:

Short sections of road aggregating 68 miles will be constructed to complete unfinished units of the transportation system. An additional 190 miles of existing roads now impassable and a serious source of erosion will be rehabilitated and stabilized to complete the transportation network. Installation cost for the 258 miles of road is estimated at $1,862,000. Annual maintenance costs will be about $17,600.

Approximately 86 miles of new trails will be built into the inaccessible areas--to provide access from landing fields and roadends. In addition, about 238 miles of existing trails, deteriorated beyond safe use, will be reconstructed. The estimated construction cost for the 326 miles of trail is about $275,200. Annual maintenance costs will be about $9,700.

Buildings will be constructed to house field personnel and equipment. The installation cost of these facilities is estimated at about $468,000 including replacement or rehabilitation of old structures. Annual maintenance and replacement costs are estimated to be $26,000.

Additional equipment includes motorized units, radios, telephones, and other similar items, estimated to cost about $265,900 with annual maintenance and replacement estimated at $40,600.

Protection personnel, over and above present personnel, includes patrolmen, tank truck and tractor operators, radio operators, and air crews. The

annual cost is estimated to be about $104,000.

The treatment of new burns is recommended as an essential emergency measure to guard against excessive damage from the inevitable fires that will occur regardless of the intensity of protection. The number of large fires and the total burned area can be reduced, although complete elimination of all fires cannot be expected. To guard against excessive flood runoff and erosion damage following these fires, it is essential that emergency treatment of burned areas be considered an integral part of the program.

As table 3 indicated, the wildland area is currently protected by three agencies. The Forest Service protection area encompasses all lands within the national forest boundary including some 2,500 acres of public domain, and about 1,300 acres of state-owned land. The California Division of Forestry protects the wildland area outside the national forest in San Luis Obispo County including the public domain and assists Kern County in the protection of the wildlands in that area. Lands similarly situated in Santa Barbara County are protected by the Santa Barbara County Forestry Department.

Summary of the intensified fire protection needs is shown in tables 4 and 5 by protection agency.

Table 4.--Installation costs of intensified fire protection needs, Santa Maria River watershed

Item	Unit	U. S. Forest Service		Calif. Div. of Forestry 1/		Santa Barbara County		Total	
		No.	Installation cost	No.	Installation cost	No.	Installation cost	No.	Total installation Cost
			Dollars		Dollars		Dollars		Dollars
Buildings	Number	27	259,000	7	56,000	17	153,000	51	468,000
Equipment	Number	26	46,700	8	70,800	8	63,100	42	180,600
Communications									
Radio	Number	25	13,300	6	3,600	8	4,900	39	21,800
Telephone	Miles	--	--	27	36,500	20	27,000	47	63,500
Roads, new	Miles	63	777,500	--	--	5	45,000	68	822,500
Roads, reconstruction	Miles	152	979,200	18	24,300	20	36,000	190	1,039,500
Trails, new	Miles	86	88,900	--	--	--	--	86	88,900
Trails, reconstruction	Miles	238	186,300	--	--	--	--	238	186,300
Total			2,350,900		191,200		329,000		2,871,100

1/ Includes Kern County requirements.

Table 5.--Annual operation and maintenance costs of intensified fire protection needs, Santa Maria River watershed

Item	U.S. Forest Service	Calif. Div. of Forestry	Santa Barbara County	Total
	Dollars	Dollars	Dollars	Dollars
Buildings	15,300	2,800	7,700	25,800
Equipment	10,500	11,800	15,600	37,900
Communications	800	1,000	900	2,700
Roads, new	17,200	--	400	17,600
Trails, new	9,700	--	--	9,700
Personnel 1/	46,300	32,000	25,700	104,000
Total	99,800	47,600	50,300	197,700

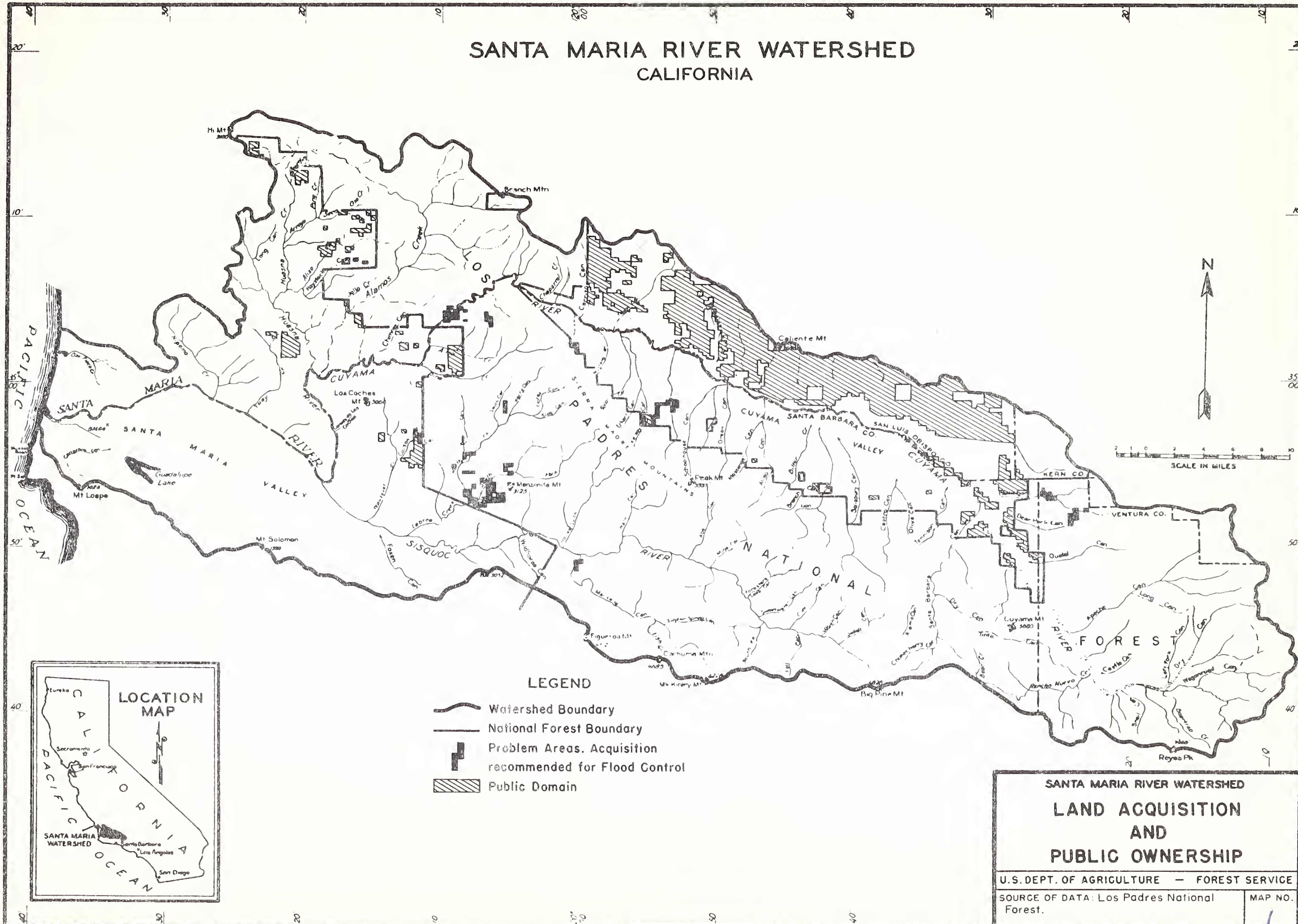
1/ Number of positions needed to operate intensified protection plan is 117 distributed as follows: national forest, 82; state, 24; county, 11.

An essential aid to accomplishing maximum fire control effectiveness is the assurance that certain tracts of land located in the extremely high fire-hazard zone receive fire prevention effort commensurate with the protection afforded adjoining lands. Some 15 tracts, totaling about 3,700 acres, are privately owned within or adjacent to the publicly owned national forest. (See map 1.) Public acquisition of these scattered tracts will be a direct method of reducing fire occurrence by limiting the present unrestricted use where threat of fire is extremely high and local cooperation limited. Certain of these tracts are significant sediment source areas which cannot be remedied under present ownership. the estimated cost of acquisition is approximately $60,000.

Rangeland Problems and their Solution

Rangeland Problems.--The problems influencing floods in this basin are attributed to (1) moderate to heavy textured soils readily susceptible to compaction by stock trampling but not subject to rapid erosion; (2) overuse of portions of the range before and during the rainy season which results in almost complete removal of the ground cover and increases soil compaction; (3) inherent peculiarities and nutritional deficiencies of the annual range type which contribute to overuse; and (4) inadequate stock distribution due to a lack of fences, water developments, and management.

Usable rangeland in the Santa Maria watershed occupies about 40 percent of the area, of which 72 percent is in the Cuyama drainage, 17 percent



BASE - U.S.F.S. ADMINISTRATIVE MAP & U.S.G.S. 1:125000 SCALE

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O.H.D. 10-17-49

in the Sisquoc, and 11 percent in the Santa Maria Valley area. Most of the rangeland in the Cuyama basin has been used intensively for about 90 years. Heavy grazing use first occurred about 1870 when large numbers of cattle, sheep, and mules were brought into that part of the watershed. The original forage was principally perennial bunch grasses which have given way to the more aggressive annuals, until now only scattered individual clumps of the perennial grasses remain. Long overuse in local areas has accelerated erosion and reduced the plant cover to a thin stunted growth of red brome grass. Palatable shrubs have been grazed to a close-cropped, rounded form in many areas, reflecting the years of intensive use. Constant trampling by many cattle has reduced greatly the infiltration rate in concentration areas.

The Caliente mountain range and the extreme upper Cuyama drainage are largely marginal. Almost all of these two areas is publicly owned. The average annual rainfall is below 5 inches, with some occurring as summer cloudbursts. The topography is very steep and rugged; the soils are thin and unproductive; summer temperatures are extreme; vegetation is sparse and of low forage quality. Grazing is limited to the spring and early summer months because of adverse climatic conditions and limited water supplies.

In the Huasna and Alamo Creek drainages, the usable range is typical of the central coastal mountain area of California. The area is capable of producing a feed high in bur clover and filaree but continued heavy use has caused an influx of less desirable species. Heavy use and excessive trampling, especially on abandoned grain fields, have brought about low infiltration capacities on 90 percent of the rangeland in the Huasna drainage. The major problem in the Alamo drainage is lack of water which has resulted in concentrated use of the few dependable water holes.

About 23 percent of the Sisquoc watershed is usable range, confined largely to the open woodland-grass foothills, potreros along the Sierra Madre Range, and the steep sagebrush slopes. Limited water supplies have resulted in overuse of the narrow, well-watered canyons. Rangeland in the lower portion of the Sisquoc, except for the abandoned cropland now used for range, does not show any evidence of active erosion. Much of the abandoned land is badly eroded and should be restricted in use until complete revegetation has been effected.

Surrounding the Santa Maria Valley, some 34 percent of the land is used for range pasture, which is contributing excessive runoff and erosion from the steeper slopes of the coastal foothills.

Institutional factors influencing the problem of land management are apparent in the ownerships and corresponding management policies of rangelands in this basin. Although a large percentage of the range is in private ownership, both large and small operators are dependent upon the use of adjoining national forest and public domain grazing resources.

Inasmuch as the public lands provide grazing for only a limited number of cattle the problem areas are to a large extent found on the private lands.

Proposed Solution to Rangeland Problems.--Flood control objectives can be accomplished through the application of good land and range management principles, including: (1) use of the proper type of stock adaptable to the topography and vegetation; (2) grazing the proper number of stock to permit only the removal of that amount of vegetation in excess of the requirements for soil protection; (3) use of the range during the proper season; (4) proper distribution of stock and eliminating areas of concentration; and (5) reseeding suitable range areas to perennial species to improve forage and watershed conditions.

Allocation of the proper number of stock in the annual type is very difficult if certain peculiarities of the annual type are not recognized and considered in determining the grazing capacities of a specific area. The great variation in forage production and the decrease in the nutritive value of the forage after it reaches maturity in the late spring are the two outstanding characteristics of the annual range type. Insurmountable as these two obstacles may appear, experience and field observation can provide a good basis for estimating the grazing capacity that will achieve the happy medium between abuse and nonuse. Both overgrazing and excessive waste must be eliminated to a degree consistent with practical management. Sufficient dry plant litter, old or current year's growth, should remain on the ground at the end of the grazing season as insurance against loss of fertile topsoil and depletion of the nitrogen content of the soil.

The diminishing nutrient value of the annual range type as the season progresses can be overcome by the feeding of concentrated supplements. This practice enables the operator to stock his range in accordance with what it produces in total carbohydrate feeds without loss of weight in stock, undernourishment, or intensive use of the range.

The average year-long stocking rate of the usable range in the Santa Maria River watershed is estimated to be 23.6 acres per animal unit.

In the early green-leaf stage the stocking rate of an average annual grass range approaches one-half acre per animal month. This decreases through the season until it reaches about 2.3 acres per animal month. The most economical use can be made of this type of range by stocking on the basis of the mature dry feed and using supplements.

To overcome the problem of excessive use of the range during the period of heavy winter rains pasture rotation is recommended.

Certain range pastures should be reserved for rotation each year maintaining all of the forage until winter use of the pasture is needed and supplementing the natural feed where necessary with hay or concentrates. Pasture rotation provides maximum ground cover for soil

protection during the winter months.

Lack of proper distribution of stock is one of the biggest problems in the annual range type in this watershed. Nevertheless, proper distribution can be accomplished (1) by fences which will limit the movement of stock, (2) by controlled adequate water supplies near forage, (3) by proper distribution of salt, (4) by distribution of supplemental feeds, (5) by range riding to work the stock over the area.

In the upper Cuyama watershed, the range is a semidesert type with most of the available forage located in canyon bottoms or on ridges. Constant trampling by many cattle has lowered the infiltration rate in forage areas. Of the 41,000 acres of rangeland about 36,000 acres are recommended for intensive management including the construction of approximately 10 miles of new fence, repairing about 5 miles of old fence, drilling about 5 wells, constructing 3 stock ponds, and developing about 12 springs.

The valley and north slopes of the Sierra Madre Mountains in the Cuyama drainage are 89,000 acres usable range of which approximately 36,500 acres are recommended for intensive management. In addition about 10 springs need to be developed, approximately 15 miles of new fence constructed and about 15 miles of old fence repaired, 7 wells drilled, and windmills and watering troughs installed.

Only 18,000 acres in the Caliente Mountains are usable range of a marginal character. Of all the areas in the watershed, this shows the largest amount of erosion due to stock grazing. Since the majority of the area is public domain and private ownership is limited to the more accessible units, the logical solution to the problem appears to be restricted use of all severely deteriorated areas under a well-planned management program. One of the primary considerations in the management program must be aimed at the adjustment of present grazing capacity to meet seasonal forage production requirements. In the vicinity of Taylor Creek the lack of water has restricted the use. Early spring losses due to larkspur poisoning can be avoided by grazing the area later in the season which would necessitate development of more water.

Infiltration rates are low due to excessive trampling which can be reduced by proper distribution and improved management.

Recommended physical improvements in the range are limited to the construction of about 14 miles of new fence, repairing about 5 miles of old fence, and the development of approximately 16 springs.

The Huasna and Alamo drainages in the lower Cuyama watershed have about 99,000 acres of usable range, approximately 45 percent of the area. Much of the rangeland is located on ridges, open potreros along the broad tops of the mountains, and the oak flats on the valley floor. Physical improvements recommended in the interests of reduced runoff include about 20 miles of new fence, reconstruction of approximately

25 miles of old fence, development of about 25 dependable springs, construction of 2 windmills and 8 stock ponds.

Pasture rotation is recommended for areas of heavy use near ranch headquarters.

About one-fourth of the Sisquoc watershed is used for grazing. Accelerated runoff from these areas necessitates improved management practices to reduce the contribution to the flood problem. To improve stock distribution and reduce heavy use of restricted areas it is recommended that about 20 miles of new fence be constructed, about 40 miles of old fence reconstructed, 3 wells drilled, windmills and troughs installed, 3 stock ponds constructed, and about 20 springs developed. In addition, a supplemental feed program will aid materially in securing proper use of the range.

In addition to the measures outlined, it is recommended that about 18,500 acres be fenced and seeded to perennial grasses. These areas are readily accessible to stock and are now subject to heavy use. At present they support only a poor stand of low-quality forage plants. Soils on these areas are good but densely compacted by stock trampling. As a result, both carrying capacity and infiltration capacity are low at present. Fencing the reseeded areas is essential for at least two years. These areas can be grazed following that period and after seed maturity. Reseeding to perennial grasses will increase forage production from 3 to 5 times. Tilling the soil, grazing when soil is dry, and maintenance of a good plant cover will increase infiltration.

Division of measures between "going" and "intensified" range improvements was determined on the basis of over-all need for flood-control purposes as shown in table 6.

Present programs of the Department contribute toward this need. The quantities that they would contribute at the 1949 rate over a 20-year period were determined and deducted from total needs. The balance represents the intensified measures as shown in table 7.

The total cost of installing the measures of the intensified range improvement is $136,500. Table 7 gives the costs by units and land ownership. The distribution of cost by sources of funds is presented in table 8. Federal contribution to the cost of measures on private land was determined from present payments for such measures by the Production and Marketing Administration.

Cost of operation, maintenance, and replacement of the measures is $6,400 as shown in table 9.

Table 6.--Needed range improvement measures by land ownership classes, Santa Maria River watershed

Treatment	Federal land		Private land		Total units
	National forest	Public domain	Within national forest	Outside national forest	
	Unit	Unit	Unit	Unit	
	Acres	Acres	Acres	Acres	Acres
Intensive management	139,200	16,600	28,300	208,600	392,700
Reseeding	7,000	--	1,500	10,000	18,500
	Miles	Miles	Miles	Miles	Miles
New fences	20	10	10	60	100
Fence reconstruction	--	--	20	80	100
	Units	Units	Units	Units	Units
Spring development	30	10	10	40	90
Wells and windmills	3	--	2	20	25
Stock ponds	5	--	5	5	15

Table 7.--Installation cost of the intensified range improvements, by land ownership classes, Santa Maria River watershed

Treatment	Federal land				Private land 1/				Total	Total cost
	National forest		Public domian		Within national forest		Outside national forest			
	Unit	Cost	Unit	Cost	Unit	Cost	Unit	Cost		
		Dollars		Dollars		Dollars		Dollars	Units	Dollars
	Acres		Acres		Acres		Acres		Acres	
Intensive management	139,200	--	16,600	--	28,300	--	208,600	--	392,700	--
Reseeding	7,000	35,000	--	--	1,000	7,100	5,500	37,100	13,500	79,200
	Miles		Miles		Miles		Miles		Miles	
Fences, new	20	12,900	10	4,200	3	2,700	17	12,400	50	32,200
Fence reconstruction	--	--	--	--	10	2,100	40	8,600	50	10,700
	Units		Units		Units		Units		Units	
Spring development	30	6,400	10	2,000	--	--	--	--	40	8,400
Wells and windmills	3	2,500	--	--	--	--	--	--	-3	2,500
Stock ponds	5	3,500	--	--	--	--	--	--	5	3,500
Total		60,300		6,200		11,900		58,100		136,500

1/ Technical assistance costs are included as part of the installation cost on private land.

Table 8.--Proposed distribution of range improvement installation costs for flood control

Item	Federal	Private	Total
	Dollars	Dollars	Dollars
Reseeding	57,100	22,100	79,200
New fences	24,700	7,500	32,200
Fence reconstruction	5,400	5,300	10,700
Spring development	8,400	--	8,400
Wells and windmills	2,500	--	2,500
Stock ponds	3,500		3,500
Total	101,600	34,900	136,500

Table 9.--Operation, maintenance, and replacement costs of the intensified range improvement measures by source of funds

Item	Federal	Private	Total
	Dollars	Dollars	Dollars
Reseeding	2,900	1,100	4,000
New fences	1,200	400	1,600
Springs	400	--	400
Wells and windmills	200	--	200
Stock ponds	200	--	200
Total	4,900	1,500	6,400

Cropland Problems and Their Solution

Cropland Problems.--Approximately 11 percent of the total watershed is cultivated, 7 percent dry-farmed, and 4 percent irrigated.

Croplands in the Cuyama watershed, particularly in the foothill belt, show excessive erosion. Less than 5 percent of the Sisquoc drainage is cropland, largely dry-farmed. Erosion has not been serious although some fields have been rilled; valley trenching and a few small gullies are in evidence. Dry-farmed land south of the Santa Maria Valley is eroding rapidly. It is gradually being abandoned to dry pasture. The higher quality cultivated land north of the valley shows accelerated erosion.

Proposed Solution to Cropland Problems.--Practically all of the 82,500 acres of nonirrigated cropland is sloping and subject to accelerated runoff and erosion. Under present farming practices, this land will revert to dry pasture within 35 to 50 years. The total conservation needs to improve present conditions are as follows:

On 25,000 acres of dry-farmed cropland in the Cuyama drainage need: (1) contour and cross-slope strip cropping, (2) residue utilization, and (3) crop rotation and green manure crops where feasible.

On 11,000 acres in the Sisquoc drainage both cultural and structural measures are needed. Structural measures include: diversion terraces, protected outlets, and minor gully controls. Cultural practices include cross-slope strip cropping, green manure crops, subsoiling, and crop rotations.

Some 45,000 acres of dry-farmed land flank the Santa Maria Valley. Cultural practices supplemented by minor structural works to control runoff and erosion on 37,300 acres include crop rotations, residue utilization, contour and cross-slope strip cropping supplemented by minor gully control structures, grassed waterways, diversion terraces, and protected outlets.

About 8,500 acres of this area, located in Bradley Canyon, Gary Canyon, Guadalupe Lake area, and Santa Maria Mesa, are the source of localized damages. The agricultural and abandoned lands in these areas are contributors tothe flood problem. At the present rate of decline in fertility and gully development, 74 percent of the land now in cultivation, or 3,770 acres, will be abandoned within the next 12 years.

Some of this land will revert to dry pasture or will be abandoned before a watershed treatment program can be installed. The simple process of reverting to a lower use or no use will not in itself remedy the floodwater and sediment sources. Stabilization by vegetative means still will be necessary. Portions of the reverted land can be returned to higher use.

To eliminate the flood and heavy sediment damage a land-use program supported by a minor structural program is recommended.

Changes in land use in the entire area surrounding the Santa Maria Valley involve conversion to grazing use of 8,500 acres of cultivated land and 3,180 acres of idle and abandoned land; 8,500 acres will require seeding. There are about 300 acres of gullied land which can be used as wildlife refuges and about 10 acres on which grassed waterways should be established. Proper pasture management and rotation will be essential to obtain maximum use from the volunteer and seeded pasture.

The supporting structural program involves practices, the types and quantities of which are estimated but not limited to: fencing of 1,300 acres; construction of 55 miles of diversion ditches and 22 gully head control structures as protection to gully heads and roadways; and about 40 gully stabilization structures.

It also requires the construction of debris barriers in several South Mesa canyons, and valley channel improvement for the protection of cropland in the valley. The debris structures in these canyons are to be designed to retain the sediment produced during a 15-year period, since it will take 10 years until the proposed land treatment program becomes fully effective in reducing the sediment load of these streams. In addition to the above structures, a bridge over Gary road will be required and the enlargement of the Gary ditch culvert under the Tepusquet Road. A section of Telephone Road will need to be raised and a riser such as the Missouri type installed to prevent further road damage and gully development.

In the Guadalupe Lake area a system of gully checks and the fencing of severely eroding gully systems is recommended to prevent future sediment damage.

On the Santa Maria Mesa, the damage to the road and the extensive gullying south of the road can be eliminated by converting the seriously eroding land to pasture and by providing safe waterways to the river. About 430 acres will be seeded to grass and legumes and grassed waterways established on about 8 acres. To carry off runoff water from the agricultural land north of the road approximately 12,000 feet of roadside ditches are needed. An overpour to the river is required for Santa Maria Creek to retard the growth of the gully system.

Such structural measures as have been described above are considered an integral part of the land treatment program.

Quantities of measures needed to improve present cropland conditions are shown in table 10. The estimated quantities and costs of measures in the recommended (intensified) land treatment and channel improvement program are shown in table 11.

Table 10.--Estimated total quantities of cropland measures needed to improve present conditions

Measure	Unit	Amount
Seeding and planting		
Conversion seeding	Acres	8,500
Grassed waterways	Acres	120
Gully planting	Miles	20
Fencing		
New construction	Miles	32
Relocation and repair of old fences	Miles	16
Increased operating costs		
Cover crops	Acres	5,000
Other conservation practices	Acres	62,000
Supplemental structures		
Diversion ditches	Miles	55
Diversion outlets	Number	300
Terrace systems including outlets	Acres	5,000
Gully stabilization structures	Number	60
Debris barriers	Number	8
Channels and appurtenant structures	Miles	7
Right-of-way	Miles	7
Gully head controls	Number	22
Farm ponds	Number	40
Road protection		
Bridges and culverts	Number	2
Curb and gutter	Feet	12,000
Risers and road elevation	Number	1

Table 11.--Estimated total quantities and costs of the intensified land treatment measures and Cuyama channel improvements

Measure	Amount	Installation cost	Annual maintenance and replacement cost
		Dollars	Dollars
Seeding and planting			
Gully planting	20 miles	70,300	2,500
Supplemental structures			
Diversion ditches	40 miles	11,200	500
Diversion outlets	300 number	79,000	1,800
Terrace systems, including outlets	3,750 acres	202,800	4,800
Gully stabilization structures	60 number	210,900	3,300
Debris barriers	8 number	202,200	2,200
Channels and appurtenant structures	7 miles	97,300	2,600
Right-of-way	7 miles	54,700	
Gully head controls	22 number	61,700	1,400
Farm ponds	10 number	21,100	500
Road protection			
Bridges and culverts	2 number	10,500)	
Curb and gutter	12,000 feet	21,600)	1,400
Risers and road elevation	1 number	11,200)	
Channel improvements			
Levee and revetment improvements	7.5 miles	258,300	9,600
Total		1/1,312,800	30,600

1/ Technical services and educational assistance costs are included as part of the installation cost based on ratio of the various measures to the total cost.

In addition to the dependent structural measures certain independent structural improvements in the Cuyama Valley to protect the irrigated lands of the valley from bank cutting, flooding, and land scour are proposed. These measures include levee and revetment improvements along reaches of the Cuyama River.

About 7 1/2 miles of revetment and 7 miles of levee are recommended on the north side of the river, and one-half mile of revetment on the south side, upstream from the highway bridge at the Cuyama school.

The cost of installation is estimated at $258,300 and annual maintenance at $9,600.

The determination of the quantities of needed measures for the intensification of the present program for both flood control and conservation of watershed lands was made from consideration of total needs and the application of measures in 1949 under "going" Department programs.

The present rate of application of measures for both flood control and conservation of watershed lands was obtained from the 1949 records of practice payments by the Agricultural Conservation Program of the Production and Marketing Administration and from rates of accomplishment in Soil Conservation Districts in the county.

The quantities of measures that can be accomplished in a 20-year installation period, at the 1949 rate, were subtracted from total needs to determine the quantities and costs of the intensified program (table 11).

Summary of Cost of Proposed Watershed Treatment Program

Total estimated installation cost of the measures is $4,380,400, as shown in table 12. Cost of the intensified fire protection measures is $2,931,100. The cropland measures will cost $1,054,500 and the rangeland measures $136,500. Channel protection work in the Cuyama Valley will require an outlay of $258,300.

The average annual cost of maintaining and operating the installation is $234,700. Distribution of costs by measures is also shown in table 12.

Table 12.--Cost of proposed program

Measures	Installation	Operation, maintenance, and replacement
	Dollars	Dollars
Fire protection	2,871,100	197,700
Land acquisition	60,000	
Range improvement		
Reseeding	79,200	4,000
Fences	42,900	1,600
Water development	14,400	800
Cropland improvement		
Seeding and planting	70,300	2,500
Supplemental structures	940,900	17,100
Road protection	43,300	1,400
Channel improvement	258,300	9,600
Total	4,380,400	234,700

Physical Effect of the Program

The primary intent of the forest, range, and cropland measures is to protect the soil against the impact of high-intensity rains. To accomplish this the forest measures aim at increasing the age and density of the brush and grass cover; the rangeland measures at increasing grass cover and reducing compaction; and the cropland measures at reducing the area of land without mulch or cover, and at reducing surface accumulation of rainwater followed by unregulated runoff.

To show the effects of these measures in comparable terms they were expressed as "resultant" cover densities. Table 13 gives these cover densities by subdrainage areas and land use. Column 2 shows present cover density which expresses the average protective condition of the land under present use. Column 6 is comparable in that it gives future total cover densities with the trends in present land use continuing and after the proposed land-use measures have become effective. Columns 4, 5, and 6 give successively the effect of first the fire trend alone, then the cumulative effect with the grazing trend added, and finally the cumulative effect of fire and grazing with the trend in agricultural land use added.

Table 13.--Resultant cover densities with and without a watershed treatment program

Subdrainage	Drainage area	Present average cover density 1/	Future condition	Cover densities by land use: Fire	Fire plus grazing	Fire plus grazing plus cultivation
	(1)	(2)	(3)	(4)	(5)	(6)
	Sq.mi.	Percent		Percent	Percent	Percent
Santa Maria at Fugler's Point	1,638	40.9	wo/program	35.0	31.7	31.6
			w/program	45.6	47.2	47.2
Upper Cuyama	410	28.7	wo/program	26.6	21.5	21.2
			w/program	34.5	37.1	37.1
Bradley Canyon	10.6	42.0	wo/program	37.5	34.7	32.7
			w/program	45.1	46.5	46.9
Sisquoc near Gary	442	46.5	wo/program	40.7	39.0	38.3
			w/program	51.5	52.2	52.4
Cuyama	912	34.2	wo/program	31.5	27.2	27.0
			w/program	38.4	40.2	40.3
Huasna	119	54.8	wo/program	50.5	46.7	46.3
			w/program	59.6	60.8	60.9
Sisquoc near Sisquoc	290	47.3	wo/program	42.8	41.6	41.6
			w/program	51.8	52.2	52.2

1/ Average cover density with present use.

The table shows that in all areas cover density will decrease over the present density if present trends in land use continue. It shows marked improvement over present conditions, if the proposed program is put into effect.

The improvement in cover density reduces not only river discharges but also sedimentation of the channels. The result is a material reduction in the "effective discharge" (see page 7, Appendix 4) and flood damages. Most of the supplemental structures proposed in the program are an integral part of the land-use measures and their effect on damage reduction is included there. Other structures are not a part of the land-use plan and their effect on damage reduction has been evaluated separately.

The combined physical effect of all these measures results in a reduction of about 38 percent in flood damages. In addition to the flood damage reduction benefits there are a series of incidental benefits.

Reduction in the number of damaging forest and grass fires and the shift toward smaller fires will reduce fire suppression costs and loss of property by fire.

Better grassland cover and improved range management will increase the grazing capacity of the land from 17,800 animal units at present to about 18,450 animal units with the program. Average cattle weights also will be increased by about 15 percent.

Cropland measures will permit continuing crop production on practically all of the 82,500 acres of nonirrigated land with yields continuing at or above present levels. Thus the income of farmers will be maintained and the agriculture of the watershed stabilized.

Sediment reduction by the program will also be of great value, should at some future time flood-control and water-conservation reservoirs be built on the Cuyama or Sisquoc Rivers.

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UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 6

PROGRAM APPRAISAL

Santa Maria Watershed, California

To accompany report on survey, flood control
Santa Maria Watershed, California

APPENDIX 6

PROGRAM APPRAISAL

Introduction

In Appendix 5 a program is developed with the aim of retarding runoff and erosion and subsequently reducing damages through

1. Improvement of cover on wild and rangeland;

2. Improvement of cropland use;

3. Supporting and supplemental structures on wild, range, and cropland.

4. Independent channel improvement measures on the Cuyama River in the Upper Cuyama Valley.

The land-use measures are complementary to each other and only their combined effect on flood-damage reduction can be evaluated accurately.

All benefits and costs are in terms of 1947 prices except as noted.

Analysis of Benefits

Flood Damage Reduction Benefits

Cuyama Valley.--The methods used in calculating damages under program conditions are the same as those described in Appendix 4 for conditions without a program. The discharge frequencies under program conditions are shown in table 5 of Appendix 3.

The average annual damages without a land-use program are $38,300. Under land-use program conditions, damages will be $23,200. The benefit is $15,100. After adjustment for the effects of the Department's "going" programs, benefits will be reduced to $10,900.

In addition to the land-use measures, and independent from them, channel stabilization works are proposed which will reduce the remaining damages of $23,200 by 80 percent. The additional benefits from the channel improvements therefore will be $18,600.

Areas South and North of Santa Maria Valley.--The measures proposed for these areas are land-use measures heavily supported by supplemental structures. This combination of measures is expected to eliminate all damages in these areas except in Bradley Canyon.

In Bradley Canyon the average annual damages without the land-use measures are $1,100; and with land-use measures, $700. Channel, debris barrier, and other structural measures will reduce the

remaining $700 by $600. Damages in other areas, namely Gary Canyon, Guadalupe Lake, Solomon Canyon, and Santa Maria Mesa, average $3,800 a year, and will be completely eliminated.

Total Flood Damage Reduction.--The construction of the Santa Maria Project will eliminate most of the flood damages which would occur in the Santa Maria Valley proper under preproject conditions. Therefore, no damage reduction benefits in this area are used in the appraisal of the USDA program. However, flood damages in the Cuyama Valley and in areas south and north of Santa Maria Valley would not be affected by the project. The total average annual flood-damage reduction due to the USDA program in these areas is $34,300, distributed as follows:

Land treatment	$15,100
Channel improvements	19,200
Total	$34,300

Reservoir Sediment Reduction Benefits with Vaquero Reservoir in Operation

The effects of the program on ground-water yields shown in figure 8, Appendix 3, have been used to calculate the associated benefits. The procedures and relations employed by the Bureau of Reclamation 1/ in arriving at benefits from percolation to ground water were used intact. The only addition has been to carry the evaluation through for 200 years instead of the 100-year period used by the Bureau of Reclamation. Table 1 shows the complete evaluation.

The benefits from the U. S. Department of Agriculture program arise from the additional acreage irrigated by the water saved because of prevention of loss of capacity of Vaquero Reservoir. Total net worth of such additional irrigation without and with the USDA program discounted at 2-1/2 percent interest, and average annual equivalent benefits for a 50-year, a 100-year, and a 200-year period are given below:

Period	Present Worth of Additional Irrigation*: W/ Program	W/O Program	Difference	Average Ann. Benefits
50-year	$50,456,000	$46,116,000	$ 4,340,000	$153,200
100-year	64,255,000	52,042,000	12,213,000	333,400
200-year	67,440,000	52,042,000	15,398,000	384,900

*Direct plus indirect.

1/ Bureau of Reclamation, Santa Maria Project, Southern Pacific Basin, California, H.D. 217, 83rd Congress, 1st Session, page 63, Table 7, and page 74, Table 8.

Table 1.-- DETERMINATION OF IRRIGATION BENEFITS DUE TO USDA PROGRAM PREVENTING SEDIMENTATION OF VAQUERO RESERVOIR

Yrs. of Vaquero Res. Operation	Annual Ground-water Yield w/o Prog.	Annual Ground-water Yield w/Prog.	Additional Acreage Irrigated 4/ on flood plain w/o Prog.	on flood plain w/Prog.	on bench land w/o Prog.	on bench land w/Prog.	Total Direct Benefits 1/ w/o Prog.	Total Direct Benefits 1/ w/Prog.	Total Benefits 3/ w/o Prog.	Total Benefits 3/ w/Prog.	Present Worth Factor 2/	Present Worth w/o Prog.	Present Worth w/Prog.
			1,000 A	1,000 A	1,000 A	1,000 A	$1,000	$1,000	$1,000	$1,000		$1,000	$1,000
1- 10	20,000	20,300	8.8	8.8	1.2	1.2	820.4	820.4	1,567.8	1,567.8	8.752	13,721	13,721
11- 20	18,800	19,800	9.7	10.3	2.0	2.0	940.2	991.8	1,796.7	1,895.3	6.837	12,284	12,958
21- 30	17,500	19,300	9.3	10.5	1.5	1.5	879.3	982.5	1,680.3	1,877.6	5.341	8,974	10,028
31- 40	15,900	18,700	9.0	10.7	0.9	0.9	821.7	967.9	1,570.3	1,849.7	4.172	6,551	7,717
41- 50	13,800	18,200	8.5	11.2	0.1	0.1	736.3	968.5	1,407.1	1,850.8	3.259	4,586	6,032
51- 60	11,400	17,500	7.1	10.9	0	0	610.6	937.4	1,166.9	1,791.4	2.547	2,972	4,563
61- 70	8,700	16,800	5.4	10.4			464.4	894.4	887.5	1,709.2	1.989	1,765	3,400
71- 80	5,600	16,200	3.5	10.0			301.0	860.0	575.2	1,643.5	1.554	894	2,554
81- 90	2,300	15,300	1.4	9.5			120.4	817.0	230.1	1,561.3	1.214	279	1,895
91-100	100	14,400	0.1	8.9			8.6	765.4	16.4	1,462.7	0.948	16	1,387
101-110	0	13,400		8.3			0	713.8	0	1,364.1	0.740		1,009
111-120		12,300		7.6				653.6		1,249.0	0.578		722
121-130		11,100		6.9				593.4		1,134.0	0.451		511
131-140		9,900		6.1				524.6		1,002.5	0.352		353
141-150		8,600		5.3				455.8		871.0	0.275		240
151-160		7,300		4.5				387.0		739.6	0.215		159
161-170		5,800		3.6				309.6		591.6	0.164		97
171-180		4,300		2.7				232.2		443.7	0.131		58
181-190		2,700		1.7				146.2		279.4	0.103		29
191-200		800		0.5				43.0		82.2	0.080		7
									Totals:		50-year	46,116	50,456
											100-year	52,042	64,255
											200-year.	52,042	67,440

1/ $86 times additional acreage irrigated on flood plain plus $53 times additional acreage irrigated on bench lands.
2/ At $2\frac{1}{2}$ percent interest.
3/ Using the Bureau of Reclamation conversion of Direct to Total Benefits: Total Benefits = Direct x 1.911
4/ 0.50 times Annual Water Yield during first 10 years; 0.62 times Annual Water Yield, 11th to 200th year. Bureau of Reclamation, Santa Maria Project, Southern Pacific Basin, California, November 1951, Table 7 and Plate 6.

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It might be well to note that some 80 percent of the benefits arise from the recognition and evaluation of an increased potential for sediment production in the watershed over present rates. This increased potential arises largely from an increased wildfire potential. Average annual equivalent benefits from the USDA program, resulting from reduced sedimentation of Vaquero Reservoir and resultant increased acreage of irrigated land, are $384,900.

Channel Sedimentation Reduction Benefits with Vaquero and Channel Improvement Operating

As a basis for evaluation, the assumption of the Corps of Engineers that the present rate of sediment production will not require any channel dredging, has been accepted. It has been further assumed that any rate greater than the present, and its associated deposition, will on the average require dredging to maintain channel capacity. The prevention of the increased sediment production rate by the USDA program therefore produces a benefit which may be evaluated in monetary terms.

The reduced sedimentation of the Santa Maria improved channel as a result of the USDA program is evaluated in monetary terms in the following tabulation.

Period after program installed	Reduction in sedimentation due to program 1/	Cost of sediment removal 2/	Present worth factor 3/	Benefits from reduced channel sedimentation 4/
Years	AF/Yr.	$/AF		$1,000
5/ 11-50	79.4	887	19.6102	1,381
50+	79.4	887	11.6360	819
				2,200

Average annual equivalent benefits = $55,000.

1/ Difference between future without U.S.D.A. program and present sedimentation rate, considering 1 flushing in 50 years (81 x 49/50 = 79.4 AF/Yr.)

2/ Twenty-five cents per cubic yard plus 15¢ per yard-mile, for an assumed 2-mile haul = $887/AF.

3/ Discounted at 2-1/2 percent.

4/ (Col. 2) x (Col. 3) x (Col. 4).

5/ No effect of program taken for first ten years; full effect thereafter.

Conservation and Other Incidental Benefits

The measures proposed in Appendix 5 and yielding the flood-damage reduction listed above also produce benefits incidental to flood-damage reduction. The sum total of these benefits is $312,500. The contributions of each of the measures to this total are described below.

Fire Protection Measures.--Two types of incidental benefits accrue from these measures--reduction in fire suppression cost and reduction of property destruction by fire.

The saving in fire suppression cost is caused by the reduced number of large fires. Better detection of fires and more rapid attack will reduce the number of acres burned by any individual fire and thus the total cost of suppression. The savings are estimated to amount to $70,000 annually.

Along with the reduction in size of fires will be a reduction in property damage by fires. Fewer fences and buildings and less feed will be destroyed. Based on past records of fire property damage, an annual saving of $20,200 is expected.

Cropland Measures.--The cropland measures yield conservation benefits estimated to be $205,400. They were calculated as follows:

At 1947 prices the weighted average net income from dry-land crops in the Cuyama drainage is about $10.50 an acre. With continuing accelerated runoff and erosion, present crops will become unprofitable within 50 years. This land will revert to dry pasture which will bring an estimated net return of $2.10 an acre. The loss will be gradual until it reaches $8.40 an acre at the end of 50 years. The average annual equivalent loss prevented by the recommended measures will be about $67,500 for that portion of the 25,000 acres of non-irrigated cropland in the Cuyama drainage to which the intensified measures apply.

In the Sisquoc drainage, average net income per acre is estimated to be $12.85. This land also will revert to grazing within 50 years with a net income of $2.10 an acre. The loss prevented on that portion of 11,000 acres to which the intensified program applies will be about $38,500 a year.

On dry-farmed land circling the Santa Maria Valley, weighted average net income is estimated to be $9.15 an acre. With present soil losses, cropping will be replaced by grazing within 35 years. Net income then will be $2.10 an acre. Loss prevented by the recommended measures will average $95,500 a year on that portion of 37,300 acres in the area to which the intensified program applies.

Increased annual return from the improvement program on the land of the minor flood source areas south and north of Santa Maria Valley is estimated at $1,200. This represents the differential in returns on rapidly deteriorating farmland and land under improved management.

Rangeland Measures.--Rangeland measures will yield conservation benefits of about $16,900. These are calculated as follows:

The total number of cattle in the watershed is estimated to be about 25,000 head. This represents 17,800 animal units. The "going" program and its accelerated phases will improve grazing land to support 18,450 animal units. It is estimated that cattle weights will increase by 15 percent. Gross income is estimated to increase by about $135,500.

The principal increase in ranch costs is $3.85 per animal unit for supplemental feed. Other ranch costs such as labor, horse and truck work, and depreciation will increase about $1.25 an animal unit. Total

increase in the ordinary operating cost is estimated to be $103,000. The net increase in income from the "going" and accelerated programs is $32,500. Of this, about $15,600 can be attributed to the effects of "going" rangeland programs, leaving a net benefit to the accelerated portion of the rangeland improvements of $16,900.

Other Nonevaluated Benefits.--Recreation use, primarily hunting, has grown rapidly in the past years as is shown in Appendix 5. This trend will continue with population growth and increase of leisure time. The proposed fire and rangeland measures will help to raise the recreational values of the watershed.

Maintenance of crop yields on dry land and improvement in grazing capacities of rangeland will help in protecting the income of the farmers and ranchers and will contribute to the social and economic stability of the watershed economy.

Improvement of rain-water infiltration on the watershed land will be beneficial to streamflow and to the water supply in the underground basins.

The watershed program will reduce to a minimum the fine sediments, ash from fires, and similar materials which are a constant threat to the proper functioning of the percolation beds. This unevaluated benefit is particularly important in view of the fact that a shortage of water already exists in the watershed and all supplies are secured by pumping from the ground-water resource.

Table 2.--Average annual monetary benefits from the recommended program

Source	Benefits
Damage reduction	$ 34,300
Sediment reduction in Vaquero Reservoir	1/ 384,900
Incidental benefits	312,500
	2/$731,700

1/ Based on prices representative of the state average 1939-44 with adjustment wherever deemed necessary to more nearly reflect long-term outlook.

2/ The expected benefits from the estimated reduced sedimentation (average annual equivalent $55,000) has not been included in total benefits because physical data were available for evaluation of only part of this sedimentation benefit, that resulting from suspended sediment; bed load was unevaluated. The benefits resulting from maintenance of percolation rates in spreading areas are also not included. These benefits will result from a reduction of surface sealing fine sediments, fire ashes, etc.

Analysis of Costs

Installation Costs

The total installation cost of the proposed program is $4,380,400 (table 3). The share which each group of measures contributes to this sum is described below.

Fire Protection Measures.--The cost is $2,931,100, including land acquisition. Tabulation of costs by items is given in table 4 of Appendix 5. This table also shows the necessary investments by protection agencies. It is proposed that the Federal Government pay 50 percent of the cost for installations on land under protection of the California Division of Forestry and of the Santa Barbara County Forestry Department, in addition to the cost for installation needed on national forest land. Thus the cost to the Federal Government would be $2,671,000, including the cost of land aquisition (table 3).

Table 3.--Installation cost of measures and distribution of costs by sources of funds

Measures	Federal	Other public	Private	Total
	Dollars	Dollars	Dollars	Dollars
Fire protection	2,611,000	260,100	0	2,871,100
Land acquisition	60,000	0	0	60,000
Cropland measures				
Seeding and planting	45,300	5,400	19,600	70,300
Supplemental structures	548,700	125,000	267,200	940,900
Road protection	19,200	24,100	0	43,300
Range improvements				
Reseeding	57,100	0	22,100	79,200
Fences	30,100	0	12,800	42,900
Water development	14,400	0	0	14,400
Channel improvements	210,500	47,800	0	258,300
Total	3,596,300	462,400	321,700	4,380,400

Cropland Improvement Measures.--Total cost of these measures is $1,054,500. The major item is supplemental structures which will cost $940,900. A breakdown of the costs by items is shown in table 11, Appendix 5. The burden of the cost of installation is distributed on the basis of benefits received and going contributions made to such measures by the Federal Government through the Production and Marketing Administration and the Soil Conservation Service. Table 3 shows this distribution of cost by sources of funds.

Rangeland Measures.--The installation cost of these measures on Federal and private land is $136,500. An itemized account is given in table 7 of Appendix 5. The distribution of these costs by source of funds is made as follows. The Federal Government is paying for all cost on land owned and controlled by the Government. It contributes to the cost of installation on private land to the same degree as is now paid by the Production and Marketing Administration. The details are given in table 3.

Channel Improvement Measures.--This applies only to the work proposed in the Cuyama Valley. Such structures as the Bradley Canyon channel are included in the group of supplemental structures under the group of cropland improvement measures. The cost of the levee and pipe and wire revetments in Cuyama Valley will be $258,300, of which the Federal Government should pay $210,500 and local interests $47,800 (table 2).

Operation, Maintenance and Replacement Costs

The annual cost for all measures is $234,700 (table 4).

Fire protection measures will cost $197,700 a year. Each of the protection agencies will pay the full cost of maintenance and operation on the installations made on land under its jurisdiction. The distribution is shown in table 4. However, the Federal Government may contribute up to 50 percent of the cost in order to assure the continued maintenance of the program.

Upkeep of cropland measures including supplemental structures is $21,000, and the cost should be distributed between local public interests and private landowners, as shown in table 4.

The maintenance of the rangeland measures will be $6,400. All the maintenance cost for installation on Federal land will be paid by the Federal Government and all maintenance cost for installation on private land will be paid by the operators. There are of course additional costs to operators for increased ordinary operating expenses due to better management. These are mentioned above under Conservation and Other Incidental Benefits (Rangeland Measures). However, they are offset by larger gross returns, and only the net difference is listed.

The maintenance cost of the channel improvements in the Cuyama Valley will be $9,600 to be paid by local public interests.

Table 4.--Operation, maintenance, and replacement cost of measures, and distribution of costs by sources of funds

Measures	Federal	Other public	Private	Total
	Dollars	Dollars	Dollars	Dollars
Fire protection	99,800	97,900	0	197,700
Cropland measures				
Seeding and planting	0	700	1,800	2,500
Supplemental structures	0	9,900	7,200	17,100
Road protection	0	1,400	0	1,400
Range improvements				
Reseeding	2,900	0	1,100	4,000
Fences	1,200	0	400	1,600
Water development	800	0	0	800
Channel improvements	0	9,600	0	9,600
Total	104,700	119,500	10,500	234,700